# Murwillumbah CBD Levee Spillway Modelling

**Draft Report**

**Revision 2**
**September 2021**

Catchment Simulation Solutions

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# 1 INTRODUCTION

The town of Murwillumbah is protected from flooding from the Tweed River by three levees. The extent of the levee system is shown in **Figure 1**. This includes the Commercial Road levee that protects most of the Murwillumbah Central Business District (CBD). The Commercial Road levee comprises a concrete panel wall that extends along the eastern side of the CBD (i.e., between Commercial Road and the Tweed River) as well as an earthen levee embankment that is located to the south of the Murwillumbah CBD. The location of the earthen levee is highlighted in **Figure 1** and a presentative view of the levee is also shown in **Plate 1**.

**Plate 1** **View of earthen levee looking west from Commercial Road taken after the peak of the March 2017 flood (note flood debris at crest of levee)**

Investigations completed as part of the 'Murwillumbah CBD Levee and Drainage Study' (Catchment Simulation Solutions, 2018) identified that there is potential for overtopping of some sections of the earthen levee during the 1% AEP flood. During preparation of this study, parts of the levee were overtopped during the flood that occurred in March 2017 (refer to flood debris line shown in **Plate 1**). As a result, the 'Murwillumbah CBD Levee and Drainage Study' recommended raising the low points in the existing levee crest and installation of a formalised spillway to allow any future overtopping to occur at a known location and in a controlled manner.

Tweed Shire Council subsequently engaged Catchment Simulation Solutions to undertake additional flood modelling to gain an understanding of the optimal levee raising and spillway arrangement. The results of this assessment are documented in the following report. It summarises the magnitude of levee raising that could be completed to improve the level of protection for properties located behind the levee while ensuring properties located outside of the levee system are not adversely impacted. It also provides an understanding of levee/spillway overtopping characteristics during larger floods that could help to inform a potential levee overtopping warning system.

# 2 EXISTING FLOOD ASSESSMENT

## 2.1 Model Updates

To gain an understanding of the potential impacts of various levee raising scenarios, it is first necessary to define flood behaviour and levee overtopping characteristics for "existing" conditions. "Existing" flood behaviour along the Tweed River and across the Murwillumbah CBD was most recently defined as part of the 'Murwillumbah CBD Levee and Drainage Study' (Catchment Simulation Solutions, 2018) using the following computer models:

- WBNM hydrologic model, which was used to represent the transformation of rainfall into runoff and generate discharge hydrographs at various locations across the Tweed River catchment; and,
- TUFLOW hydraulic model, which was used to route the discharge hydrographs from the hydrologic model and produce information on key flood characteristics, such as flood levels, depth, extent and velocities.

The above models were also used as part of the current study to define existing flood behaviour. However, the TUFLOW model was first updated to incorporated detailed ground survey of the existing earthen levee that was recently collected by Council surveyors. The levee crest profile was also refined to reflect the original design elevations based on plans titled *'Murwillumbah Earthen Levee: Commercial Road to High School Oval'* (Tweed Shire Council, 1990).

The WBNM model was also updated to include new hydrologic inputs to allow discharge hydrographs for the 0.5% AEP flood to be produced (the original model only assessed the 1% AEP and 0.2% AEP floods). The discharge hydrographs for the 1% AEP, 0.5% AEP and 0.2% AEP floods for the Tweed River at Murwillumbah are provided in **Plate 2**.

## 2.2 Results

The updated models were used to simulate flood behaviour for the design 1% AEP, 0.5% AEP and 0.2% AEP floods for existing conditions. Peak flood water depths were extracted from the results of the flood simulations and are presented in **Figures 2**, **3** and **4**.

Peak floodwater surface profiles were also extracted immediately south of the existing levee crest and are presented in **Figure 5**. Also included on **Figure 5** is the profile of the existing levee crest (extracted from the design plans).

The information presented in **Figure 2** and **Figure 5** confirms that the existing levee is predicted to be overtopped during the 1% AEP flood. As shown in **Figure 5**, the levee is overtopped by around 50 mm along much of its length. The overtopping depths are predicted to approach 400mm in the vicinity of the Murwillumbah High School sports fields. This also corresponds to the location where the levee system first begins to overtop.

**Figure 5** also shows that the full length of the earthen levee embankment is predicted to be overtopped during the 0.5% AEP and 0.2% AEP floods. Typical levee overtopping depths during the 0.5% AEP flood are predicted to be around 300mm. During the 0.2% AEP peak overtopping depths are most commonly around 500mm

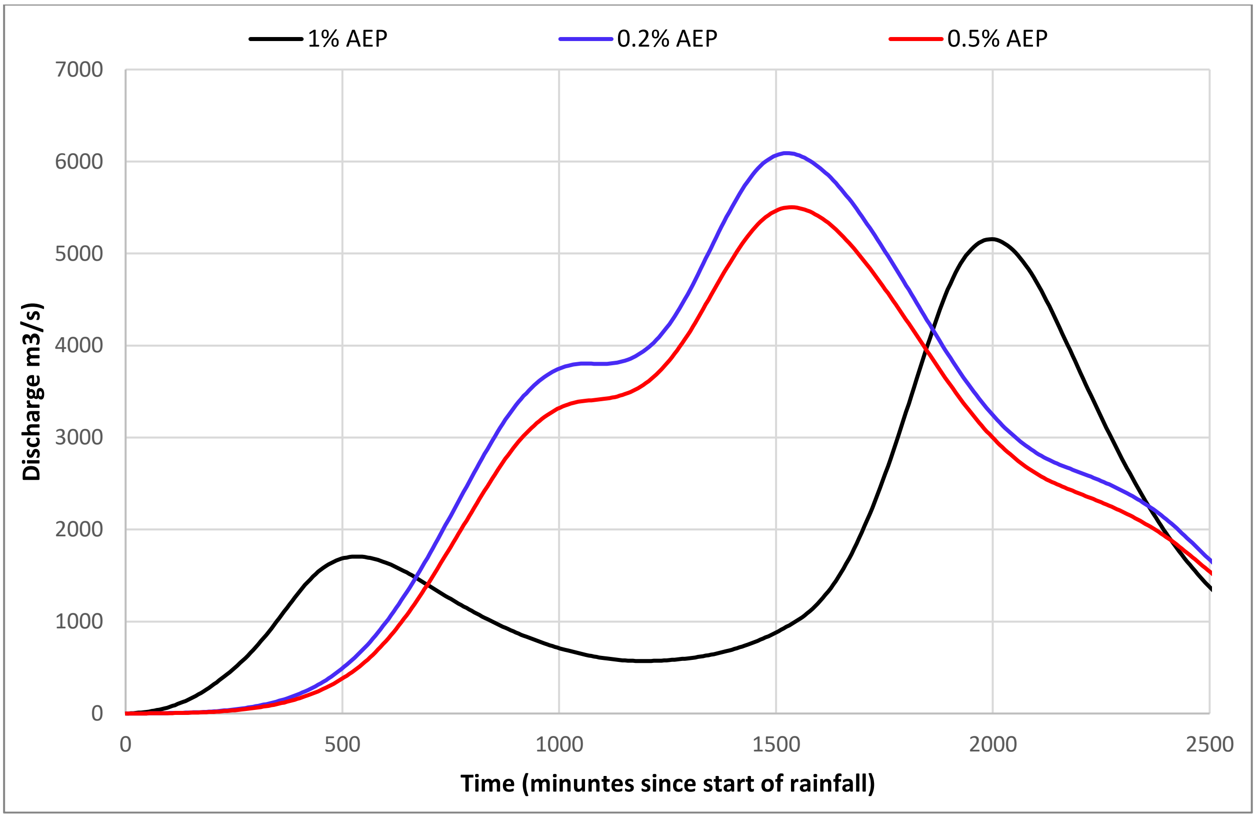



**Plate 2** Design discharge hydrographs for the Tweed River at Murwillumbah

Levee overtopping characteristics for each design flood were also extracted and are provided in **Table 1**. This includes peak overtopping depths and overtopping durations for each design flood (the peak overtopping depths refer to the earthen embankment portion of the levee and exclude the sports field).

**Table 1** Existing Levee Overtopping Characteristics

| Design Flood | Max Overtopping Depth (m) | Peak Flow Across Levee ($m^3/s$) | Overtopping Times (hours since start of rain) | | Duration of Overtopping (hours) |
|---|---|---|---|---|---|
| | | | Start | End | |
| 1% AEP | 0.17 | 12.8 | 33.3 | 36.3 | 3.0 |
| 0.5% AEP | 0.31 | 118 | 23.3 | 31.3 | 8.0 |
| 0.2% AEP | 0.47 | 307 | 22.0 | 32.7 | 10.7 |

Although the levee is only predicted to be overtopped for 3 hours during a 1% AEP flood, the overtopping duration is predicted to increase to approximately 8 hours during the 0.5% AEP flood and nearly 11 hours during a 0.2% AEP flood. As shown in **Table 1**, more than 300 $m^3/s$ of floodwater is predicted to spill across the earthen levee at the peak of the 0.2% AEP flood resulting in peak water depths of at least 4 metres across a significant area located behind the levee. This includes some areas with more than 5 metres depth of water.

Lower floodwater depths are predicted during the 1% AEP flood (typically less than 2 metres). In addition, Commercial Road is predicted to remain dry during the 1% AEP flood, which will ensure that "rising road" evacuation access will be available for most properties located behind the levee.

However, water depths are still predicted to exceed more than 4 metres across a large area during the 0.5% AEP flood and Commercial Road would also be inundated to depths of more than 2 metres. Therefore, the results of the existing flood simulations confirm that during floods that exceed the 1% AEP event, the flood risk for areas located behind the levee increases significantly.

# 3 ASSESSMENT OF LEVEE RAISING SCENARIOS

## 3.1 Overview

The following chapter presents the outcomes of additional flood modelling that was completed to assess the impacts that different levee raising scenarios would have on existing flood behaviour. The goal of the assessment was to determine the optimal levee height that would improve the level of protection for properties located behind the levee while ensuring properties located outside of the levee system are not adversely impacted.

Three levee raising scenarios were included in the assessment:

- Scenario A: Earthen section of levee raised by 50mm.
- Scenario B: Earthen section of levee raised by 100mm.
- Scenario C: Earthen section of levee raised by 200mm.

A comparison of the levee crest profiles adopted under each levee raising scenario are provided in **Figure 6**.

**Figure 6** also shows that a spillway was provided in the vicinity of the Murwillumbah High School sports fields and the characteristics of this spillway remained the same under each levee raising scenario. The goal of the spillway is to allow water to start spilling into the Murwillumbah CBD in a controlled manner away from habitable areas.

The outcomes of iterative modelling for the different levee raising scenarios determined that a spillway with a width of 110 metres would provide the best overall outcome under each of the levee raising scenarios. It was assumed that no changes to the existing sports field would be completed as part of the levee raising works. That is, elevations across the levee would remain "as is" to ensure the existing functionality of the sports field would remain unchanged in non-flood times (refer **Plate 3**).

## 3.2 Assessment of Levee Raising Scenarios

### 3.2.1 Scenario A: Earthen Section Raised 50mm

Scenario A investigated elevating the design levee crest by 50 mm. This scenario will elevate the levee to roughly the same height as the peak 1% AEP profiles. However, it will not prevent overtopping of the levee at its western end (as indicated by the negative freeboard in **Table 2**).

Scenario A was included within an updated version of the TUFLOW model and the TUFLOW model was used to re-simulate each design flood (i.e., 1% AEP, 0.5% AEP and 0.2% AEP floods).

Flood level difference mapping was prepared to show the impact that the levee raising scenario would have on existing flood levels during each design flood. The difference mapping was prepared by subtracting "base" design flood levels (as discussed in Chapter 2) from the Scenario A flood levels. This provides a contour map showing the location and magnitude of changes to flood levels associated with the Scenario A levee raising. The difference mapping for Scenario A is provided in **Appendix B**.

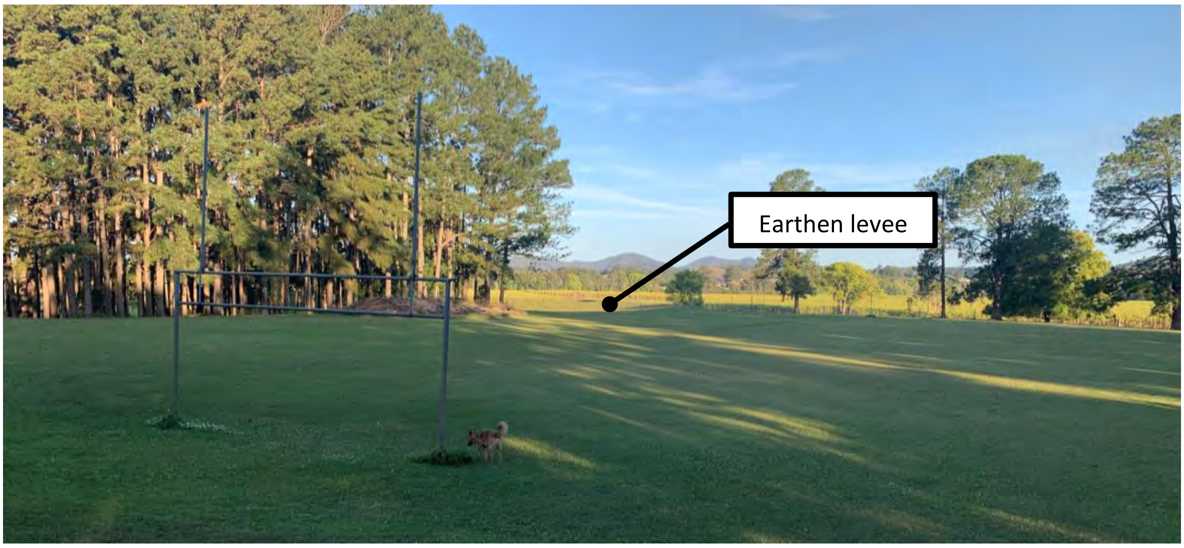



**Plate 3** View looking south-east showing Murwillumbah High School sports field in foreground and earthen levee in background

**Table 2** Key Features of Levee Raising Scenarios

| Scenario | Crest Elevation (mAHD) | | Freeboard Provided (m) | | |
|---|---|---|---|---|---|
| | Min | Max | 1% AEP | 0.5% AEP | 0.2% AEP |
| A | 7.31 | 7.56 | -0.04 to 0.02 | -0.33 to -0.22 | -0.61 to -0.44 |
| B | 7.36 | 7.61 | 0.01 to 0.07 | -0.28 to -0.17 | -0.56 to -0.39 |
| C | 7.46 | 7.71 | 0.11 to 0.17 | -0.18 to -0.07 | -0.46 to -0.29 |

The following information was also extracted from the results of the modelling:

- The number of properties exposed to changes in flood extent (i.e., newly flooded and now flood free) and the number of properties subject to changes in above flood flooding (i.e., newly flooded above floor and no longer flooded above floor) are provided in **Table 3**.
- Levee and spillway overtopping depths and flows are provided in **Table 4**.
- Levee and spillway overtopping times/durations are provided in **Table 5**.
- Typical flood level reduction afforded behind the levee along with the typical flood level increase outside of the levee are provided in **Table 6**.

The difference mapping in **Appendix B** and the results documented in **Table 6** shows that Scenario A is predicted to produce small reductions in flood levels (i.e., <0.05 metres) behind the levee during the 1% AEP and 0.2% AEP flood while reductions of more than 0.3 metres are predicted during the 0.5% AEP. No significant increases in flood level are predicted at any location during the 1% AEP or 0.2% AEP floods. Small, localised increases in flood level are predicted immediately south of the levee during the 0.2% AEP flood, however, they are not predicted to exceed 0.02 metres.

Table 3 Summary of Property Impacts

| Scenario | Number of Properties Exposed to Flood Extent Changes | | | | | | Number of Properties Exposed to a Change in Above Floor Flooding | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1% AEP | | 0.5% AEP | | 0.2% AEP | | 1% AEP | | 0.5% AEP | | 0.2% AEP | |
| | Now Wet | Now Dry | Now Wet | Now Dry | Now Wet | Now Dry | Newly Flooded | No Longer Flooded | Newly Flooded | No Longer Flooded | Newly Flooded | No Longer Flooded |
| A | 0 | -2 | 0 | -3 | 0 | 0 | 0 | -3 | 0 | -34 | 0 | 0 |
| B | 0 | -2 | 0 | -5 | 0 | 0 | 0 | -4 | +1 | -55 | 0 | 0 |
| C | 0 | -2 | 0 | -9 | 0 | 0 | 0 | -4 | +1 | -90 | 0 | 0 |

Table 4 Overtopping Characteristics for Levee Raising Scenarios

| Scenario | Design Flood | Maximum Overtopping Depth (m) | | Peak Flow ($m^3/s$) | | |
|---|---|---|---|---|---|---|
| | | Levee | Spillway | Levee | Spillway | Total |
| Existing | 1% AEP | 0.02 | 0.17 | 5.0 | 7.7 | 12.7 |
| | 0.5% AEP | 0.21 | 0.31 | 90 | 28 | 118 |
| | 0.2% AEP | 0.47 | 0.45 | 250 | 57 | 307 |
| A | 1% AEP | 0.02 | 0.17 | 0.5 | 7.8 | 8.3 |
| | 0.5% AEP | 0.15 | 0.31 | 74 | 29 | 103 |
| | 0.2% AEP | 0.47 | 0.45 | 224 | 58 | 282 |
| B | 1% AEP | NA | 0.17 | NA | 7.8 | 7.7 |
| | 0.5% AEP | 0.11 | 0.31 | 60 | 30 | 90 |
| | 0.2% AEP | 0.47 | 0.45 | 200 | 59 | 259 |
| C | 1% AEP | NA | 0.17 | NA | 7.8 | 7.8 |
| | 0.5% AEP | 0.06 | 0.32 | 34.5 | 30.9 | 65.4 |
| | 0.2% AEP | 0.47 | 0.45 | 154 | 60 | 214 |

**Table 5** **Overtopping Durations for Levee Raising Scenarios**

| Scenario | Design Flood | Start of Overtopping (hours since start of rain) | | End of Overtopping (hours since start of rain) | | Duration of Overtopping (hours) | |
|---|---|---|---|---|---|---|---|
| | | Levee | Spillway | Levee | Spillway | Levee | Spillway |
| Existing | 1% AEP | 33.7 | 33.3 | 35.3 | 36.3 | 1.7 | 3.0 |
| | 0.5% AEP | 24.0 | 23.3 | 30.3 | 31.3 | 6.3 | 8.0 |
| | 0.2% AEP | 22.7 | 22.0 | 31.7 | 32.7 | 9 | 10.7 |
| A | 1% AEP | 33.7 | 33.3 | 35.0 | 36.3 | 1.3 | 3.0 |
| | 0.5% AEP | 24.0 | 23.3 | 30.0 | 31.3 | 6.0 | 8.0 |
| | 0.2% AEP | 22.7 | 22.0 | 31.3 | 32.7 | 8.7 | 10.7 |
| B | 1% AEP | NA | 33.3 | NA | 36.3 | NA | 3.0 |
| | 0.5% AEP | 24.0 | 23.3 | 29.7 | 31.3 | 5.7 | 8.0 |
| | 0.2% AEP | 22.7 | 22.0 | 31.3 | 32.7 | 8.7 | 10.7 |
| C | 1% AEP | NA | 33.3 | NA | 36.3 | NA | 3.0 |
| | 0.5% AEP | 24.0 | 23.3 | 29.3 | 31.3 | 5.3 | 8.0 |
| | 0.2% AEP | 22.7 | 22.0 | 31.3 | 32.7 | 8.7 | 10.7 |

Table 6 Summary of Flood Level Impacts

| Scenario | Typical Flood Level Reduction Behind Levee (metres) | | | Typical Flood Level Increase South of Levee (metres) | | |
|---|---|---|---|---|---|---|
| | 1% AEP | 0.5% AEP | 0.2% AEP | 1% AEP | 0.5% AEP | 0.2% AEP |
| **A** | -0.04 | -0.31 | -0.01 | 0.00 | +0.00 | +0.00 |
| **B** | -0.04 | -0.61 | -0.03 | 0.00 | +0.01 | +0.01 |
| **C** | -0.04 | -1.06 | -0.04 | 0.00 | +0.02 | +0.02 |

The results presented in **Table 3** also show that Scenario A is predicted to result in 2 fewer properties being flooded above floor level in the 1% AEP flood and 3 fewer properties are predicted to be subject to above floor flooding during the 0.5% AEP flood. No increases in above floor flooding are predicted during any of the simulated design floods.

**Table 4** also shows that Scenario A is not predicted to change the duration of overtopping during any of the design floods as the High School sports field would remain the location of first overtopping (unchanged from base case conditions).

On balance, Scenario A provides the smallest flood level reductions for properties located behind the levee during the 0.5% AEP flood, although it does provide comparable benefits to the other levee raising options during the 1% AEP flood and 0.2% AEP flood. It is also the only scenario that provides reductions in flood extents and above floor inundation during the range of design floods simulated while producing negligible (i.e., <20mm) flood level increases/adverse property impacts in areas located outside of the levee.

### 3.2.2 Scenario B: Earthen Section Raised 100mm

Scenario B investigated elevating the design levee crest by up to 100 mm. As shown in **Table 2**, this scenario would require a levee crest elevation of 7.36 mAHD to be provided near Commercial Road and a crest elevation of 7.61 mAHD near the Murwillumbah High School sports fields. This scenario would provide a levee that will be elevated above the peak 1% AEP flood profile along its full length. However, water would still be permitted to overtop the spillway.

Scenario B was included within an updated version of the TUFLOW model and the TUFLOW model was used to re-simulate each design flood. Flood level difference mapping was prepared to quantify the location and magnitude of changes in existing flood levels associated with the Scenario B levee raising and is presented in **Appendix C**. A range of other levee/spillway overtopping characteristics and property impacts were extracted from the results of the modelling and are provided in **Table 6**, **Table 3** and **Table 4**.

**Table 6** shows that Scenario B provides similar flood level reductions to Scenario A for areas contained behind the levee during the 1% AEP and 0.5% AEP floods. However, it offers a notable improvement during the 0.5% AEP flood where flood level reductions of more than 0.6 metres are predicted behind the levee. This is predicted to result in (refer to **Table 3**):

- 1% AEP flood: 4 properties now being identified as "flood free" and 2 fewer properties being exposed to above flood flooding.
- 0.5% AEP flood: 55 properties now being identified as "flood free" and 5 fewer properties being exposed to above flood flooding.

- 0.2% AEP flood: No change in above floor flooding or flood affectation.

As shown in **Appendix C** and **Table 6**, Scenario B is not predicted to generate any significant flood level increases during the 1% AEP flood. During the 0.5% AEP flood, flood level reductions of up to 0.02 metres are predicted immediately south of the levee (although this is contained to open space). During the 0.2% AEP event, flood level increases of up to 0.04 metres are predicted immediately south of levee. More modest flood level increases are predicted to extend into small sections of South Murwillumbah (i.e., +0.01 metres) as well as across East Murwillumbah (+0.02 metres). The differences across East Murwillumbah are associated with very small flood level increases (i.e., <+0.01m) within the main river channel that results in the East Murwillumbah levee being overtopped for a slightly longer period (resulting in a greater volume of water entering the East Murwillumbah area).

As shown in **Table 3**, this is predicted to result in 1 additional property being exposed to above floor flooding in the 0.2% AEP flood.

Overall, Scenario B affords some significant benefits to properties located behind the levee, particularly during the 0.2% AEP flood. However, the increases in above floor flooding makes this option difficult to support without associated mitigation measures to offset the adverse flood impacts (e.g., creating protective levees and/or raising of impacted properties).

### 3.2.3 Scenario C: Earthen Section Raised 200mm

Scenario C investigated elevating the design levee crest by 200 mm. As shown in **Table 2**, this equates to a levee crest elevation of 7.46 mAHD near Commercial Road and a crest elevation of 7.71 mAHD near the Murwillumbah High School sports fields. The section of Commercial Road that adjoins the eastern section of the earthen embankment will also need to be elevated by approximately 100 mm. This will increase the technical challenges and cost associated with implementing this levee raising scenario (i.e., ensuring suitable approach road grades are provided and ensuring access to properties located west of Commercial Road is maintained).

Scenario C was included within an updated version of the TUFLOW model and the TUFLOW model was used to re-simulate each design flood. Flood level difference mapping was prepared to quantify the location and magnitude of changes in existing flood levels associated with the Scenario C levee raising and this mapping is provided in **Appendix D**. A range of other levee/spillway overtopping characteristics and property impacts were extracted from the results of the modelling and are provided in **Table 6**, **Table 3** and **Table 4**.

**Table 6** shows that Scenario C provides the most significant flood level reductions behind the levee during the 0.5% AEP flood (i.e., flood level reductions of more than 1 metre). However, the benefits during the 1% AEP flood and 0.2% AEP floods are more modest (i.e., flood level reductions are not predicted to exceed 0.05 metres). Nevertheless, these reductions are sufficient to afford the following benefits:

- 1% AEP flood: 13 properties now being identified as “flood free” and 4 fewer properties being exposed to above flood flooding (i.e., identical to Scenario B).
- 0.5% AEP flood: 13 properties now being identified as “flood free” and 126 fewer properties being exposed to above flood flooding (a significant improvement over Scenario B).

- 0.2% AEP flood: 2 properties now being identified as “flood free” and 8 fewer properties being exposed to above flood flooding (a slight improvement over Scenario B).

Although **Appendix C** and **Table 6** show that Scenario C is predicted to generate very similar flood level impacts during the 1% AEP flood relative to Scenario B, more significant flood level increases are predicted during the 0.5% AEP and 0.2% AEP floods. This includes flood level increases of at least 0.01 metres that extend from Bray Park down to Quarry Road at South Murwillumbah during the 0.5% AEP flood. Although the flood level increases are not as expansive during the 0.2% AEP floods, the increases are still predicted to extend into private properties at Bray Park. The flood level increases are sufficient to result in 1 additional property being newly exposed to above floor flooding during the 0.5% AEP flood.

Therefore, although Scenario C provides the most significant benefits of the levee raising scenarios considered, particularly during the 0.5% AEP flood, it also affords the most significant adverse flood impacts. Therefore, it is not recommended as part of any future levee raising/rehabilitation.

### 3.2.4 Preferred Levee Raising Scenario

Each of the levee raising scenarios evaluated in this chapter afford varying degrees of advantages and disadvantages. In general, more substantial levee raising will produce more significant flood level reductions behind the levee but more significant and expansive flood level increases outside of the levee (including increases in above floor flooding).

Overall, levee raising Scenario A is recommended as it is the only option that provides reductions in flood levels and above floor flooding behind the levee while not increasing the flood exposure for areas located outside of the levee.

## 3.3 Assessment of Levee Overtopping Characteristics

As discussed, the Scenario A levee raising (i.e., +50mm) is recommended as part of the proposed earthen levee rehabilitation works. To assist with the future detailed design of the levee rehabilitation, detailed analysis of the hydraulic modelling results for Scenario A was completed.

The analysis focused on the following components:

- Confirming where the elevated levee is first predicted to overtop
- Confirming peak depths and velocities across the spillway
- Confirming peak depths and velocities across the earthen embankment

Peak water depths with the preferred levee raising option in place were extracted for each design flood and are provided in **Figures 7** to **9** in **Appendix A**. Peak velocity outputs were also extracted for each design flood and are presented in **Figures 10** to **12**. Also highlighted on **Figures 10** to **12** are the locations and magnitude of the maximum velocity across the spillway and earthen embankment.

The depth and velocity outputs show that the 0.2% AEP flood is predicted to produce the highest depths and velocities across the levee as well as across the spillway. More specifically:

- Spillway: the peak 0.2% AEP velocity is predicted to reach 4.6 m/s between the two sports fields. The peak water depth at this location is predicted to be 1.3 m
- Earthen Embankment: The peak 0.2% AEP velocity is predicted to reach 3.7 m/s about 330 metres east of Commercial Road on the town side of the levee (i.e., just north of the crest). The peak depth at this location is predicted to be 1.6 m.

A further review of the velocity results confirms that velocities across the spillway are also predicted to exceed 4 m/s during the 0.5% AEP flood (although velocities across the earthen embankment are contained below 2.5 m/s). During the 1% AEP flood, velocities are generally less than 2 m/s with the exception of a small areas near the spillway/sporting fields.

The 'Queensland Urban Drainage Manual' (IPWEA, 2018) suggests that even well vegetated areas are liable to erode once the velocity exceeds 3 m/s. Therefore, if only grass was retained across the spillway there is potential for scour to occur during the 0.2% AEP and 0.5% AEP floods. There is also potential for scour of the earthen embankment during the 0.2% AEP flood which will increase the potential for failure of the levee during such a flood. Therefore, strong consideration should be given to providing additional scour protection measures as part of the design of the rehabilitation (e.g., concrete/rock protection). Once design plans are prepared for the levee rehabilitation it is also recommended that the probable maximum flood is simulated to confirm that the scour protection measures will also perform in a satisfactory manner during an extreme flood.

The time series of water depth results were also extracted to understand where the levee and spillway is first predicted to overtop and how the overtopping will propagate over time. The outcomes of this assessment are present in **Plate 4** to **Plate 6** for the 0.2% AEP flood.

This information suggests that, during a 0.2% AEP flood, the spillway will be activated around 22 hours after the initial onset of rainfall, and it would take a further 50 minutes before the spillway capacity is exceeded and water begins to overtop the western part of the earthen embankment. The earthen embankment will then be overtopped from west to east. This is a preferable overtopping sequence as the section of the levee that adjoins existing residential development (i.e., adjacent to Commercial Road and Elizabeth Street) will be overtopped last and will provide the greatest opportunity for evacuation during a levee overtopped event. However, it will only take around 10 minutes from the time the earthen embankment is overtopped at its western end until the full length of levee is overtopped. Accordingly, there would be very little time available to evacuate if people/the SES waits until the spillway capacity is exceeded before commencing evacuation. Therefore, it is suggested that opportunities to install a warning system near the spillway be explored as part of the rehabilitation to maximise the opportunities for evacuation during a levee overtopping event.

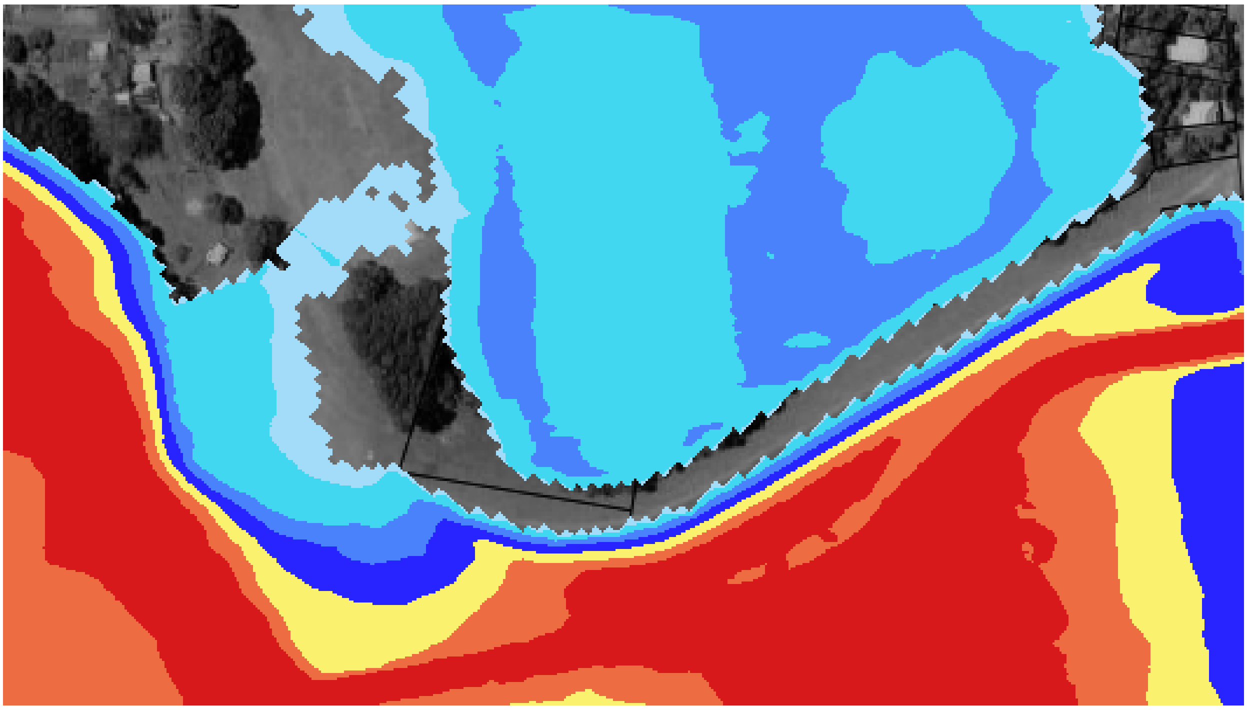


**Plate 4** **Spillway/High School Sports Field First Begin to over top (21 hours and 50 minutes after start of rainfall)**

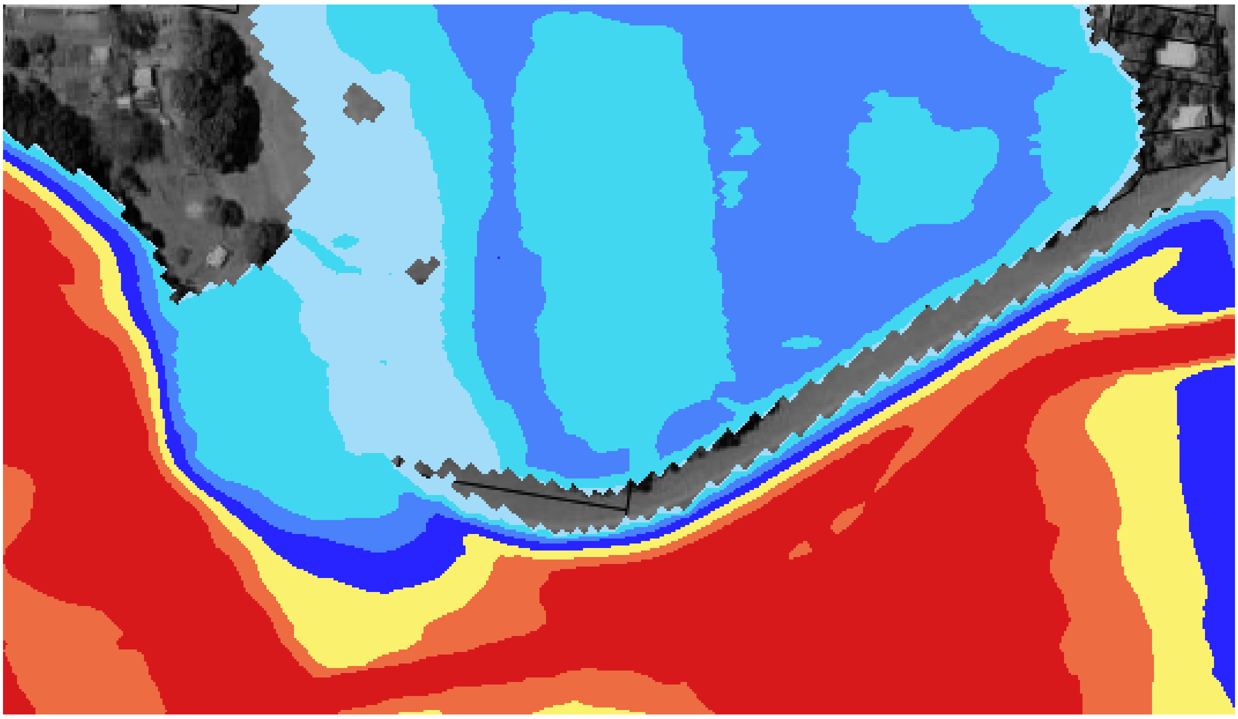


**Plate 5** **Spillway capacity is exceeded, and western section of earthen embankment begins to over top (22 hours and 40 minutes after start of rainfall)**

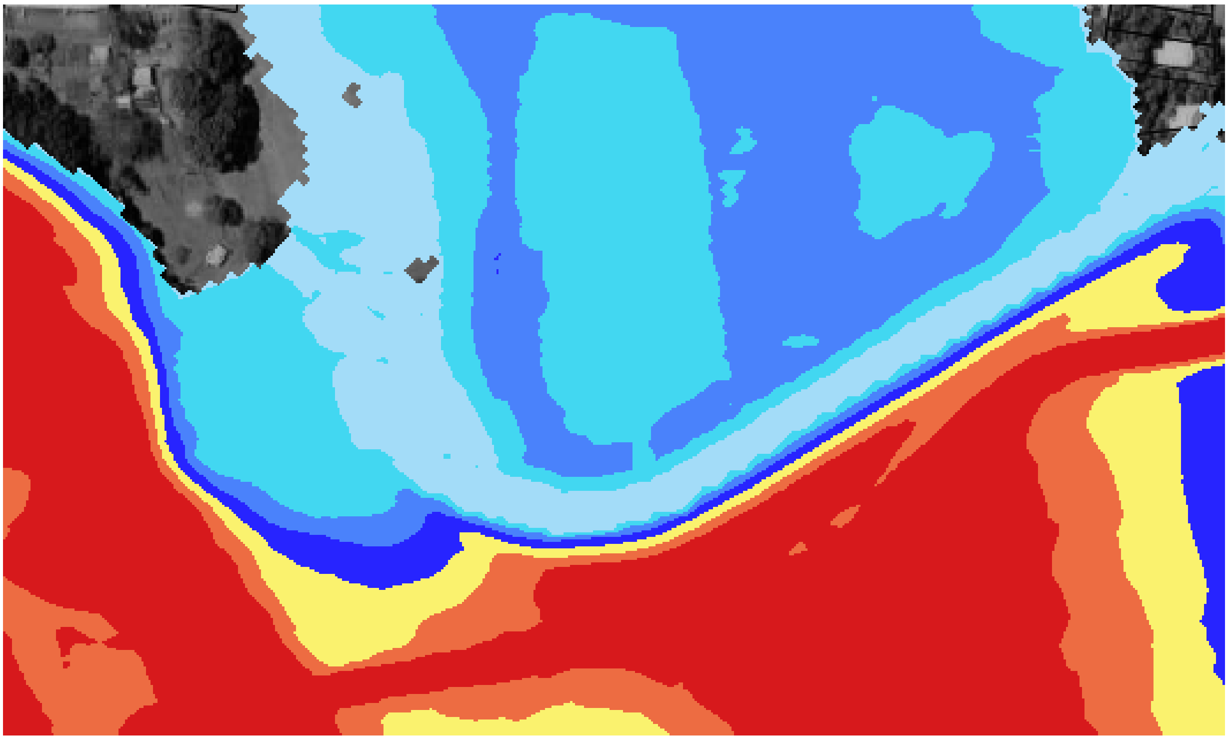


Plate 6 The full length the earthen embankment is overtopped (22 hours and 50 minutes after start of rainfall)

# 4 CONCLUSION

This report has presented the outcomes of flood modelling that was completed to support the design of the proposed rehabilitation of the earthen embankment section of the Commercial Road levee. The investigation aimed to provide an understanding of the optimal levee raising and spillway arrangement that could be incorporated as part of the rehabilitation work. This aimed to maximise the hydraulic benefits for properties located behind the levee while minimising adverse impacts for properties located outside of the levee.

Three levee raising options were explored as part of the study:

- Scenario A: Earthen section of levee raised by 50mm.
- Scenario B: Earthen section of levee raised by 100mm.
- Scenario C: Earthen section of levee raised by 200mm.

Under all three levee raising scenarios it was assumed that the Murwillumbah High School sports fields would not be altered and would function as a spillway for the levee system.

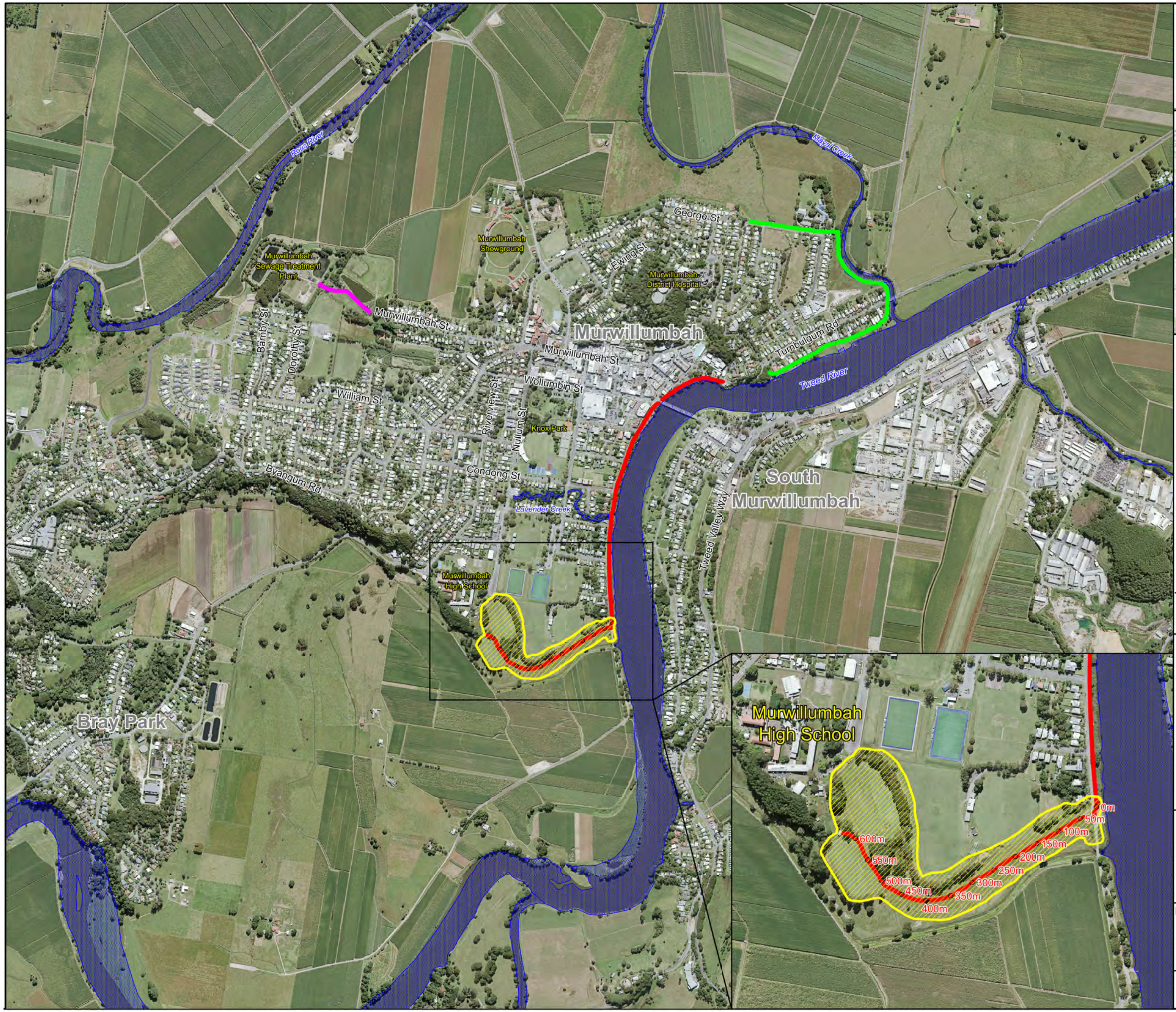
The outcome of the modelling confirms that each of the 3 levee raising options will afford flood level reductions across multiple properties contained behind the levee. However, Scenario B and C are predicted to produce increases in flood levels for some locations outside of the levee. The flood level increases are sufficient to increase the number of properties exposed to above floor flooding during the 0.5% AEP flood. Therefore, Scenario A (i.e., 50mm increase in height) is the only scenario that is predicted to afford flood level reductions behind the levee without increasing the flood affectation of existing properties located outside of the levee. Therefore, the Scenario A levee raising is recommended to move forward into the detailed design of the levee rehabilitation.

A detailed analysis of the results from the Scenario A modelling determined that, during a 0.2% AEP flood, the spillway of the levee system (i.e., Murwillumbah High School sports fields) would begin to overtop around 22 hours after the initial onset of rainfall. Around 50 minutes would then transpire before the spillway capacity is exceeded and the earthen embankment begins to overtop. Only 10 minutes of additional time would be required for the complete length of the earthen levee to be overtopped. Therefore, a flood warning/notification system should be considered as part of the rehabilitation to assist with providing as much advanced warning of the levee being overtopped as possible to permit evacuation for properties located behind the levee.

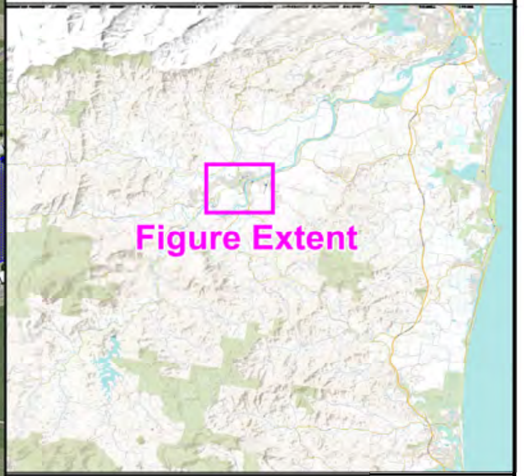
Peak velocity outputs also suggest sections of the spillway and earthen embankment would be exposed to velocities of well above 3 m/s during the 0.5% AEP and 0.2% AEP floods. This would be sufficient to scour existing grass and place the integrity of the levee and spillway into question. Therefore, scour protection measures should also be considered at high velocity locations to ensure the rehabilitated levee can withstand the expected velocities during a future overtopping event.

Once design plans are prepared for the levee rehabilitation it is also recommended that the probable maximum flood is simulated to confirm that the scour protection measures will also perform in a satisfactory manner during an extreme flood. It is also suggested that a levee failure simulation is completed to understand areas that may be exposed to a significant flood hazard/risk during such an event. This will help to inform emergency response planning once the rehabilitation is complete.

# APPENDIX A
## FIGURES




TWEED SHIRE COUNCIL




**LEGEND**

- Study Area
- Levee 1 - Commerical Road
- Levee 2 - East Murwillumbah
- Levee 3 - Dorothy Street
- Profile Chainage (refer Figure 5 & 6)

Notes:

Aerial photograph date: 2015

N
W E
S

Scale: 1:14,500 (A3)

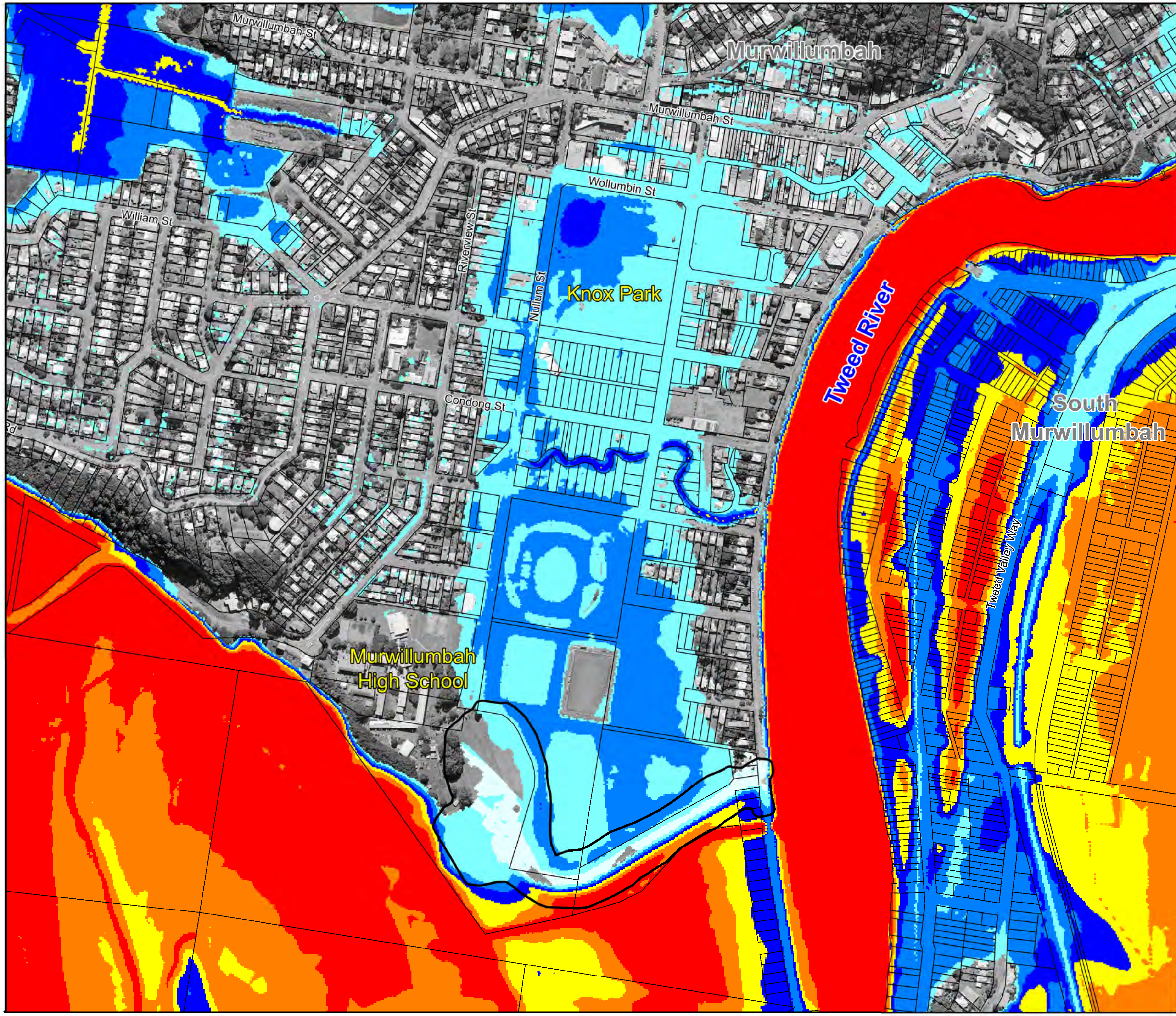
0 0.5 1.0
Km

**Figure 1: Existing Murwillumbah CBD Levees**

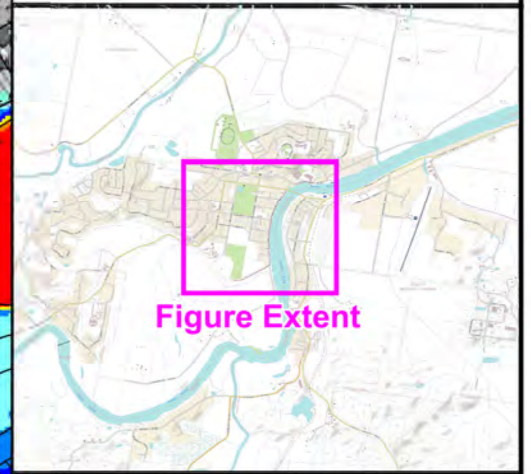
Prepared By:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Fig 1 Existing Murwillumbah CBD Levees.wor




TWEED SHIRE COUNCIL




**LEGEND**

Depths (m)

0.00 - 0.15
0.15 - 1.00
1.00 - 2.00
2.00 - 3.00
3.00 - 4.00
4.00 - 5.00
>= 5.00

Study Area

Notes:

Aerial photograph date: 2015

N W E S

Scale: 1:6,000 (A3)

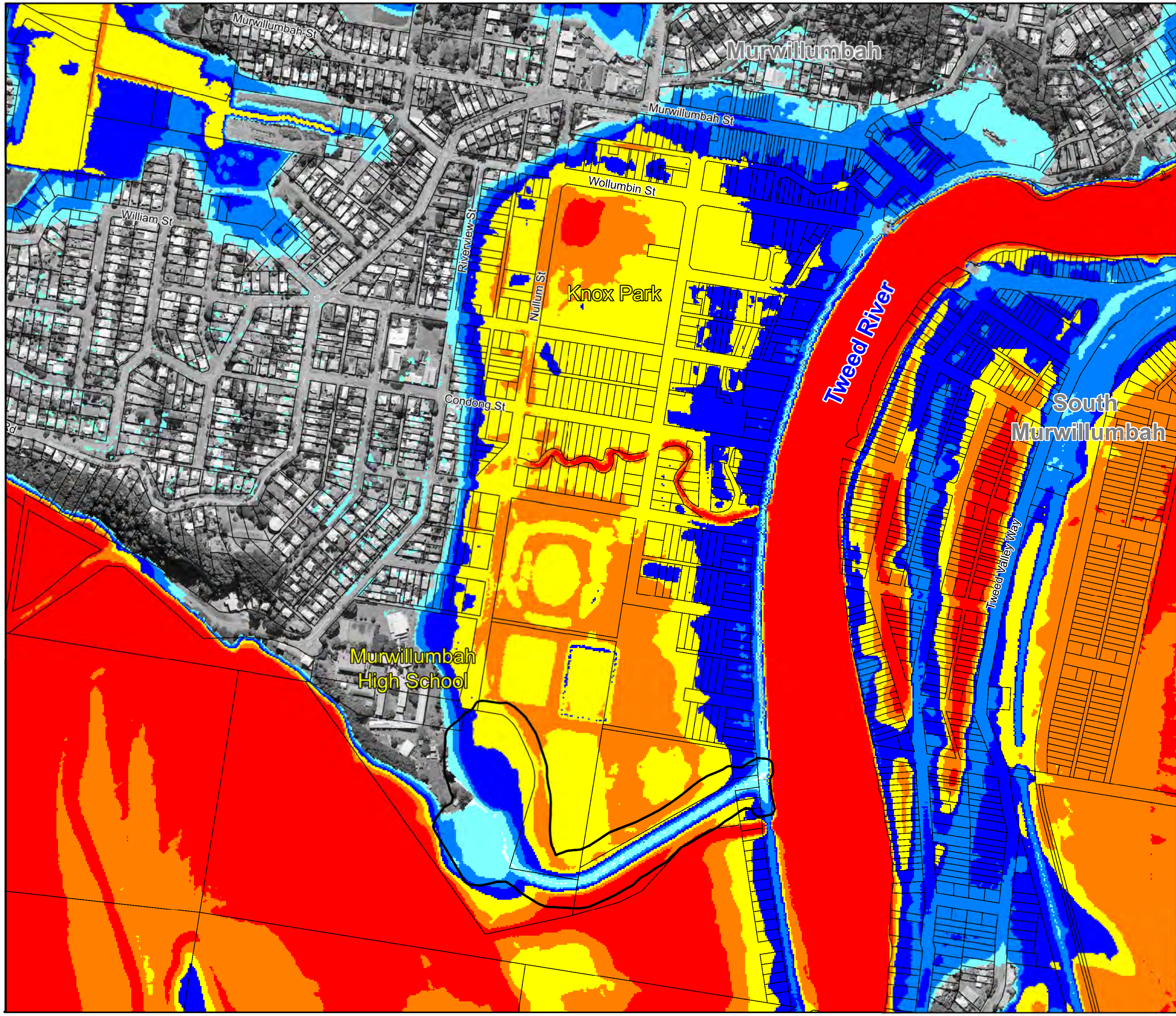
0 0.15 0.30 Km

**Figure 2: Existing Floodwater Depths for the 1% AEP Flood**

Prepared By:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Fig 2 Existing Floodwater Depths for the 1% AEP Flood.wor




TWEED SHIRE COUNCIL

Figure Extent

**LEGEND**

Depths (m)
- 0.00 - 0.15
- 0.15 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- 3.00 - 4.00
- 4.00 - 5.00
- >= 5.00

Study Area

Notes:
Aerial photograph date: 2015

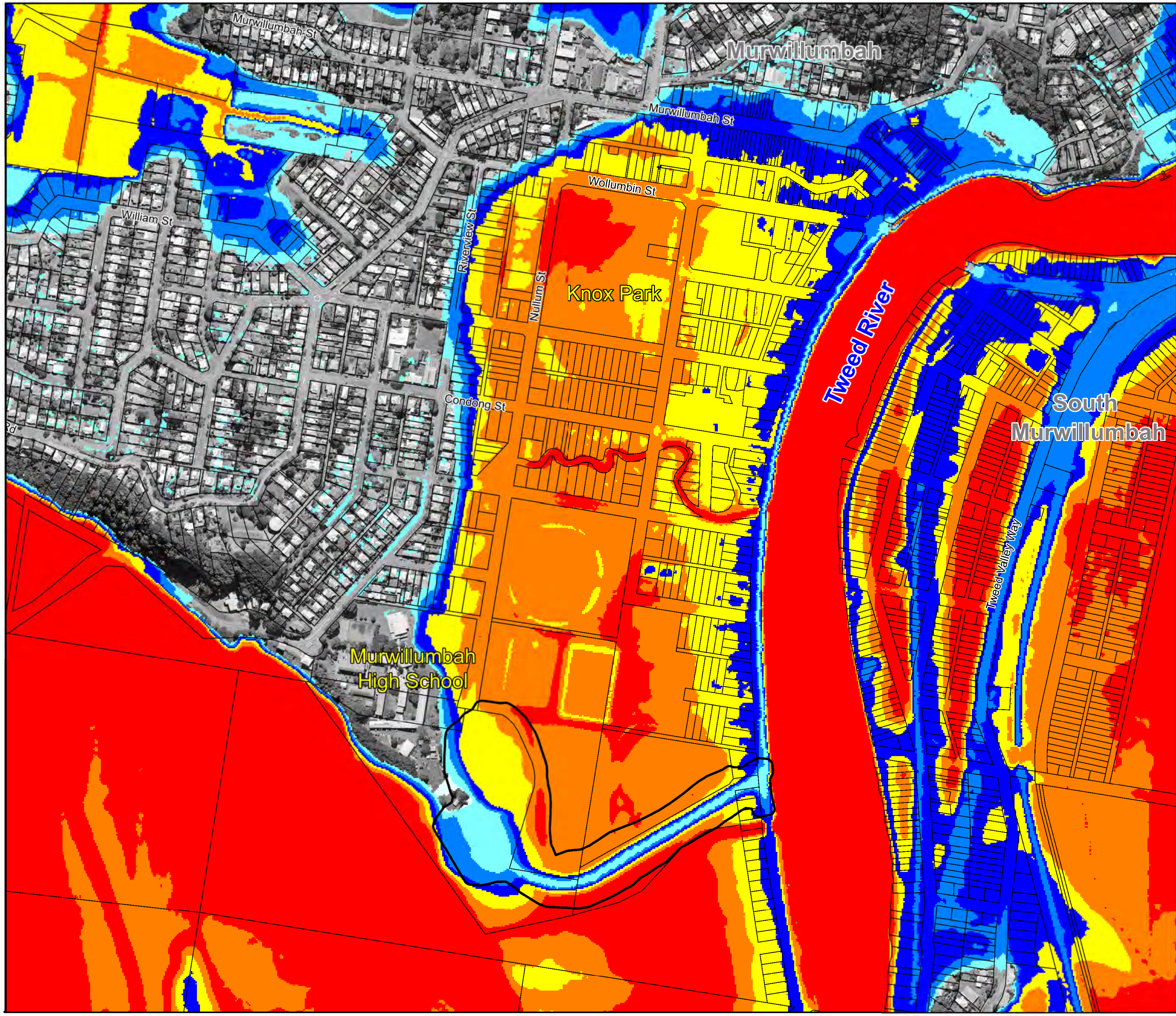
N W E S

Scale: 1:6,000 (A3)
0 0.15 0.30 Km

**Figure 3: Existing Floodwater Depths for the 0.5% AEP Flood**

Prepared By:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Fig 3 Existing Floodwater Depths for the 0.5% AEP Flood.wor




TWEED SHIRE COUNCIL

Figure Extent

## LEGEND

Depths (m)

- 0.00 - 0.15
- 0.15 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- 3.00 - 4.00
- 4.00 - 5.00
- >= 5.00
- Study Area

Notes:

Aerial photograph date: 2015

N W E S

Scale: 1:6,000 (A3)

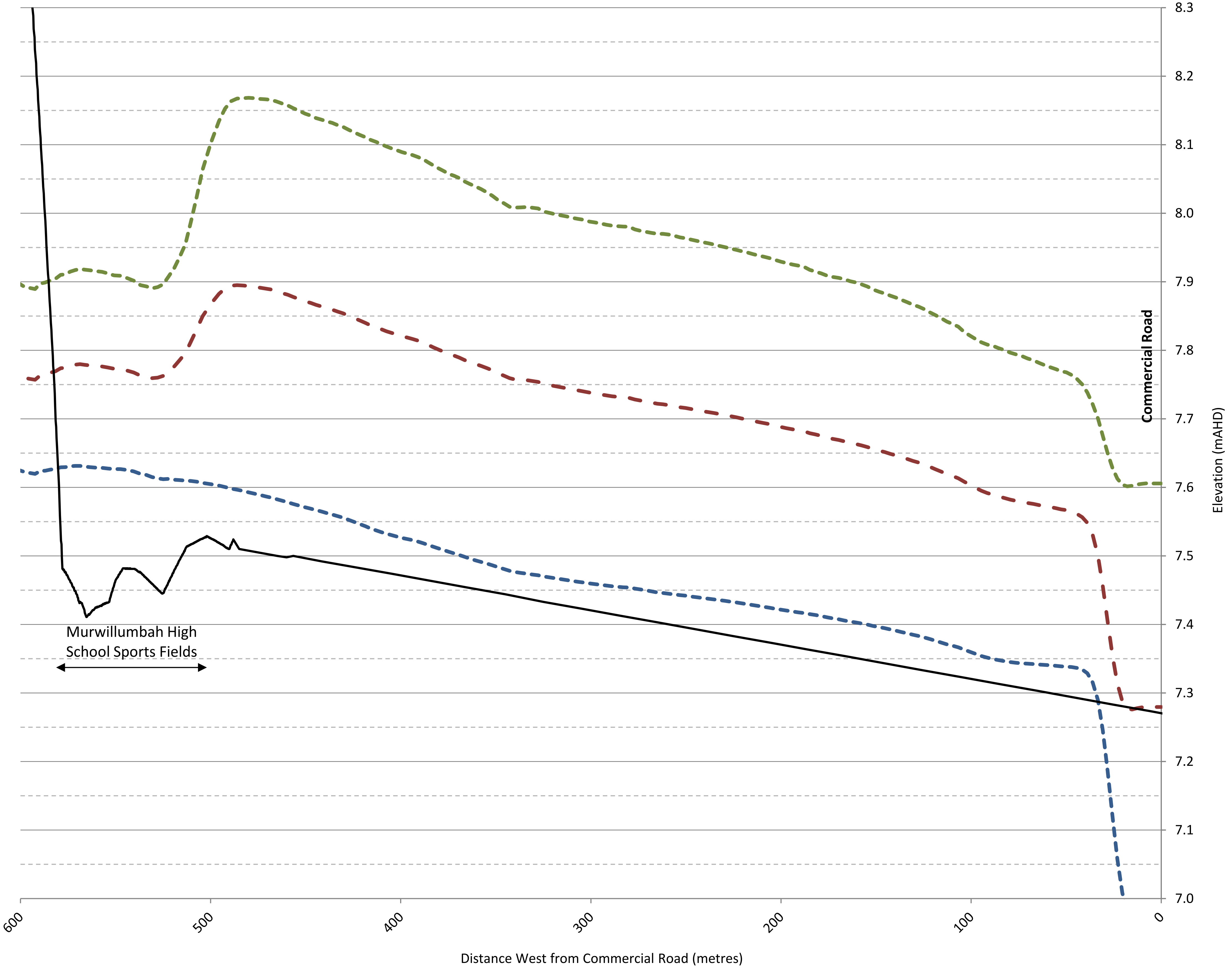
0 0.15 0.30 Km

**Figure 4:**
**Existing Floodwater Depths for the 0.2% AEP Flood**

Prepared By:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Fig 4 Existing Floodwater Depths for the 0.2% AEP Flood.wor




TWEED SHIRE COUNCIL

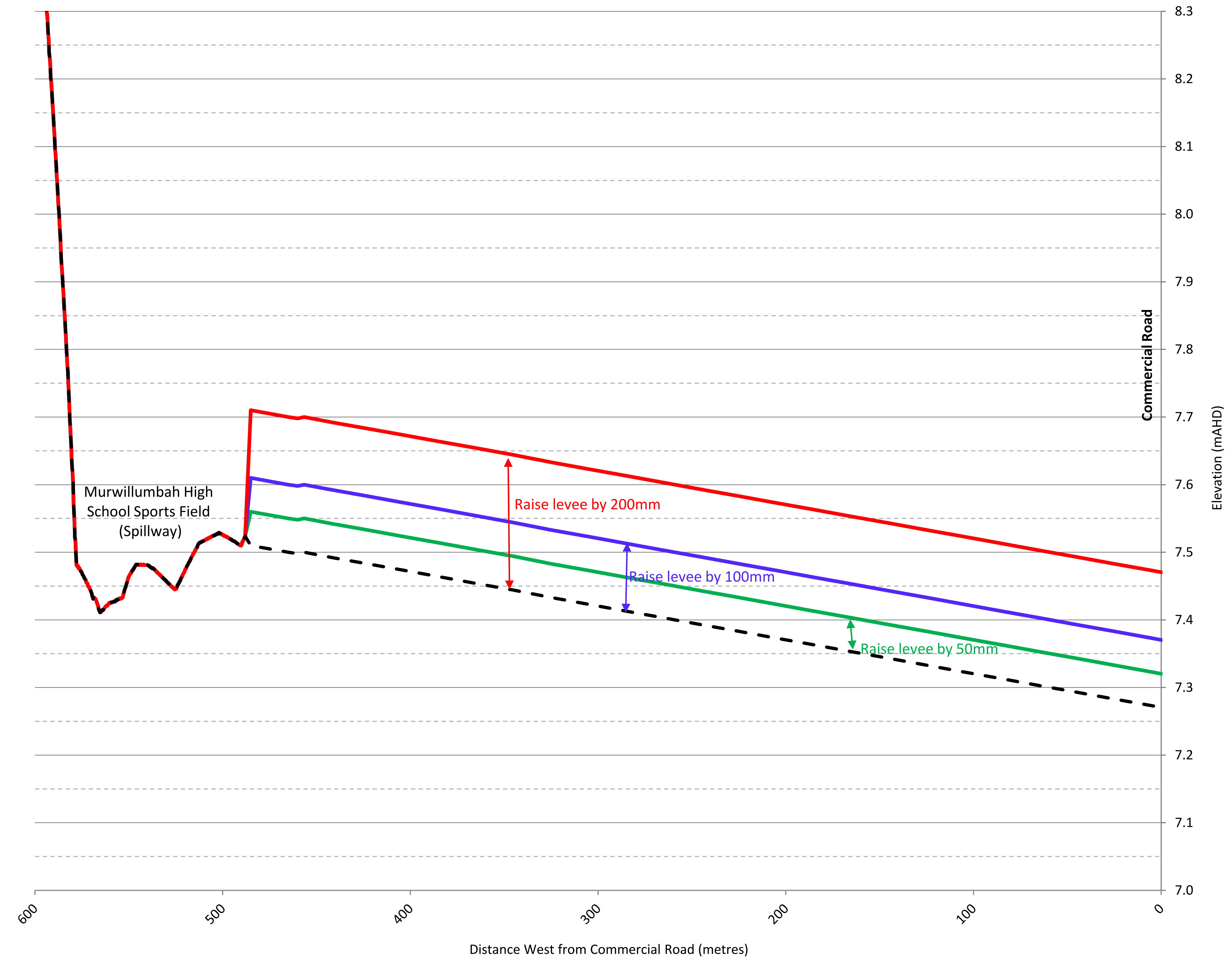
**LEGEND:**



# Figure 5: Existing Levee Crest and Water Surface Profiles


Prepared By:
Catchment Simulation Solutions
Suite 1 Level 10, 170 Philip Street
Sydney, NSW, 2000


File Name: Murwillumbah Levee Figures.xls




TWEED SHIRE COUNCIL

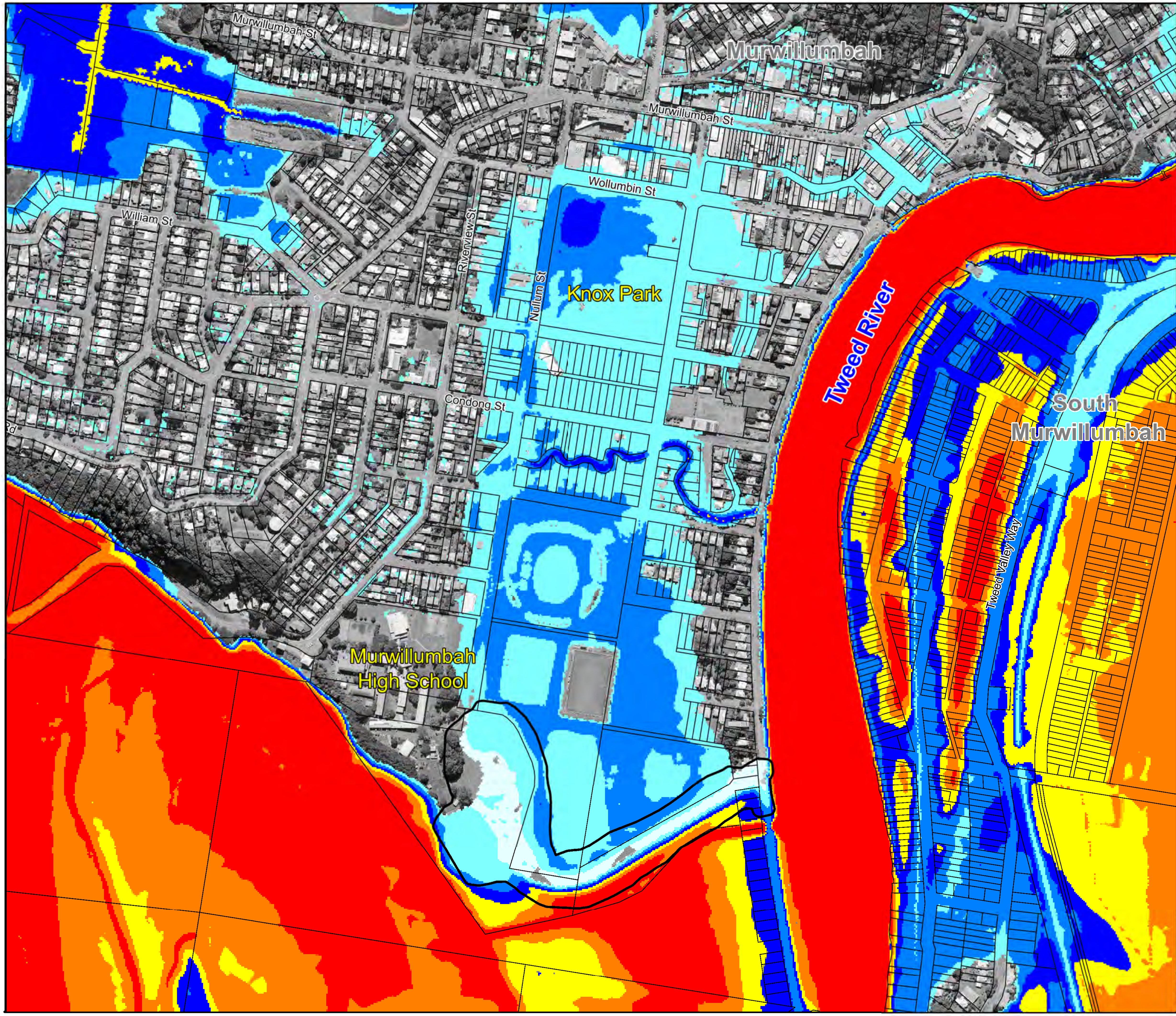
**LEGEND:**

- Scenario A
- Scenario B
- Scenario C
- Design Levee Crest

# Figure 6: Levee Crest Profiles for Levee Raising Scenarios

Prepared By:
Catchment Simulation Solutions
Suite 1 Level 10, 170 Philip Street
Sydney, NSW, 2000

File Name: Murwillumbah Levee & WSP.xls




TWEED SHIRE COUNCIL

## LEGEND

Depths (m)

- 0.00 - 0.15
- 0.15 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- 3.00 - 4.00
- 4.00 - 5.00
- >= 5.00
- Study Area

Notes:

Aerial photograph date: 2015

N W E S

Scale: 1:6,000 (A3)

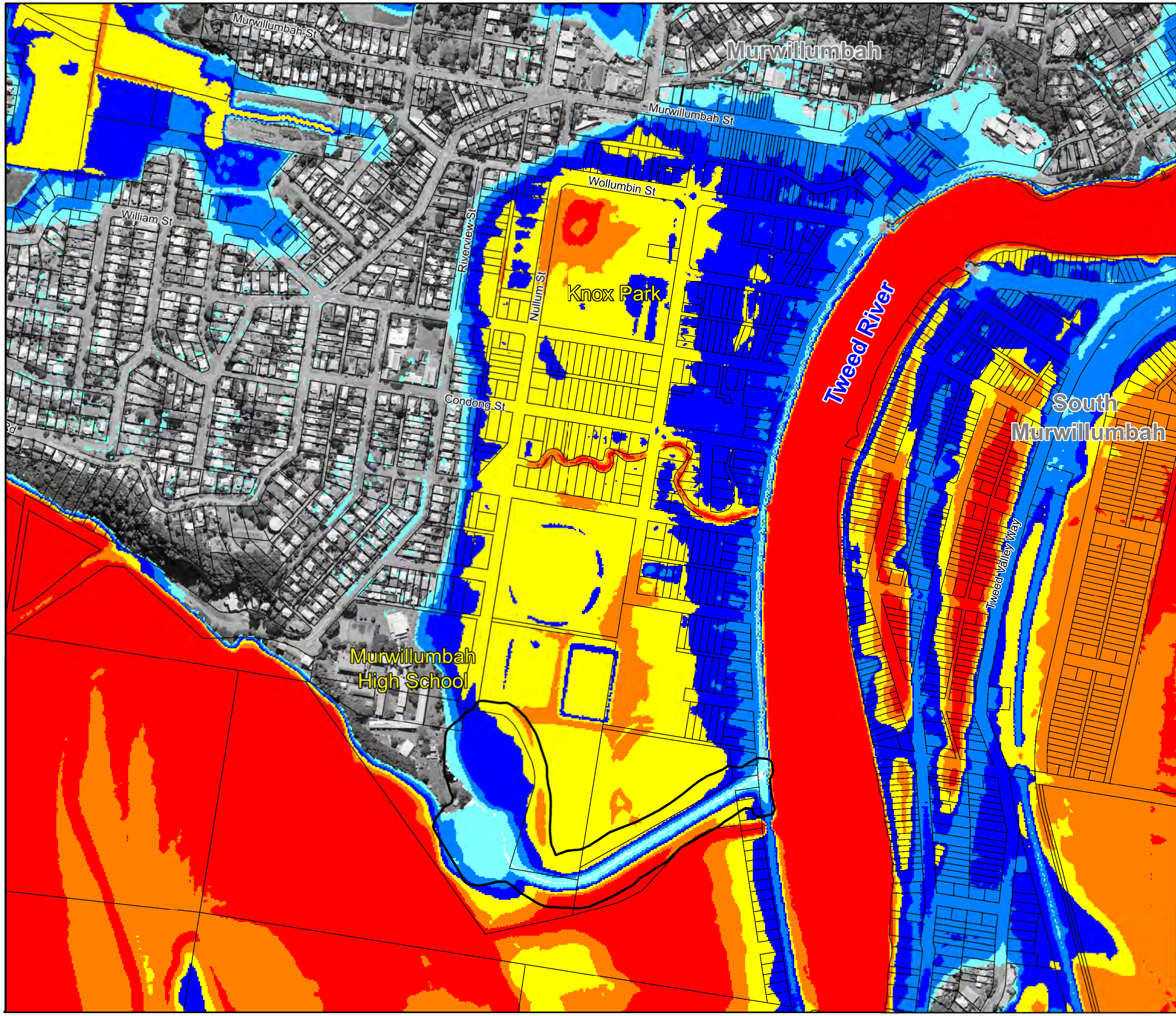
0 0.15 0.30 Km

**Figure 7: Floodwater Depths for the 1% AEP Flood for Preferred Levee Raising Scenario**

Prepared By:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Fig 7 Depths for the 1% AEP Flood for Preferred Scenario.wor




TWEED SHIRE COUNCIL

## LEGEND

Depths (m)

- 0.00 - 0.15
- 0.15 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- 3.00 - 4.00
- 4.00 - 5.00
- >= 5.00
- Study Area

Notes:

Aerial photograph date: 2015

N W E S

Scale: 1:6,000 (A3)

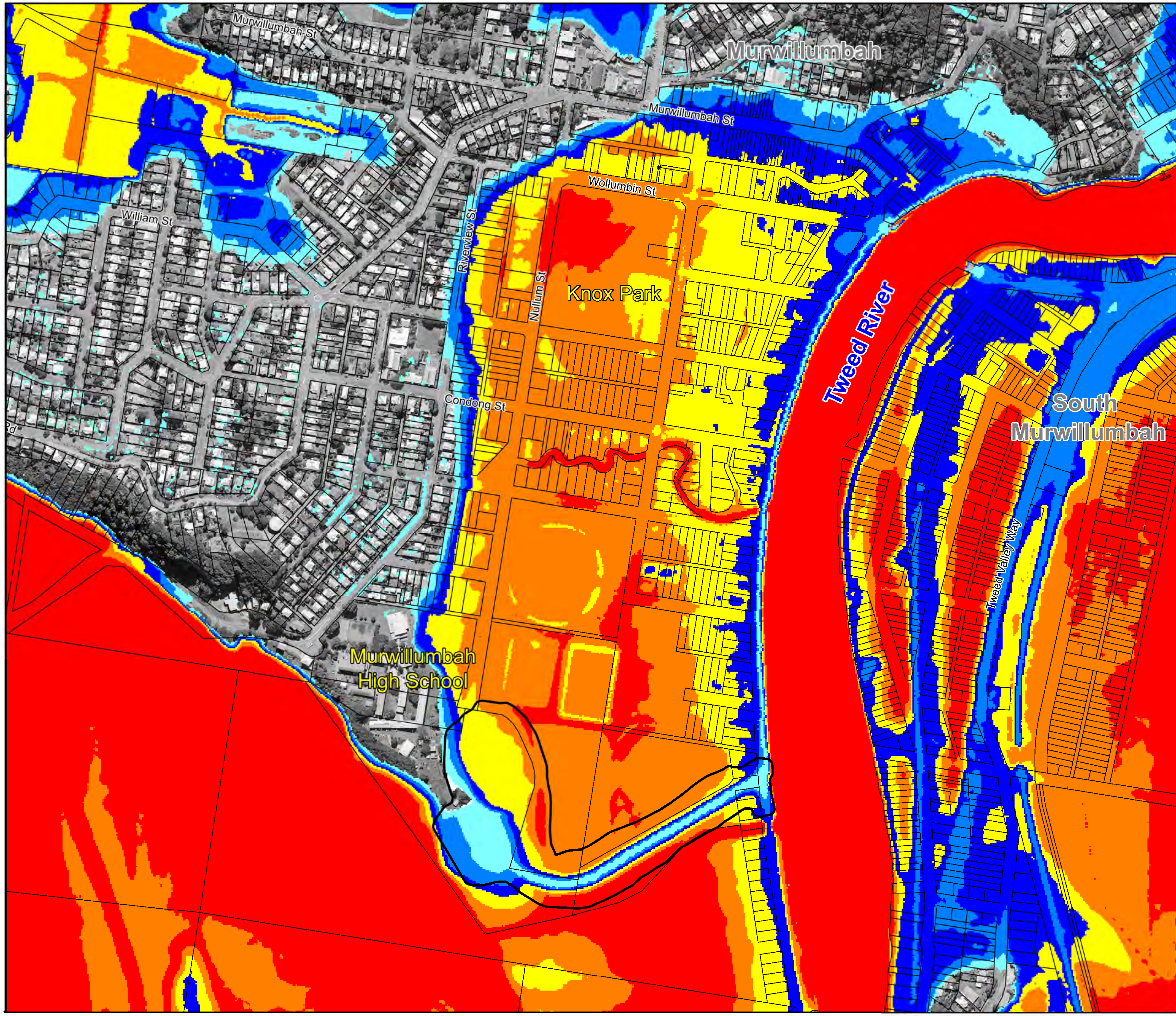
0 0.15 0.30 Km

**Figure 8: Floodwater Depths for the 0.5% AEP Flood for Preferred Levee Raising Scenario**

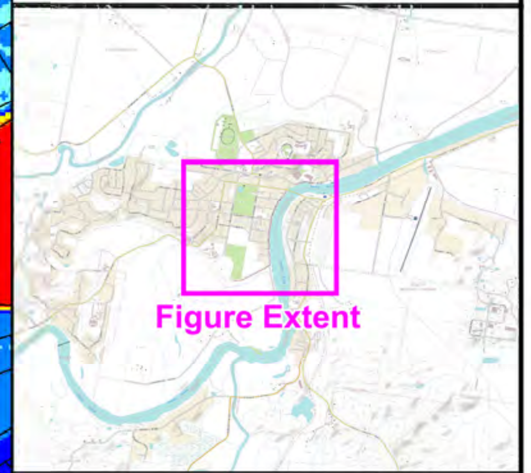
Prepared By:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Fig 8 Depths for the 0.5% AEP Flood for Preferred Scenario.wor




TWEED SHIRE COUNCIL




**LEGEND**

Depths (m)

- 0.00 - 0.15
- 0.15 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- 3.00 - 4.00
- 4.00 - 5.00
- >= 5.00
- Study Area

Notes:

Aerial photograph date: 2015

N W E S

Scale: 1:6,000 (A3)

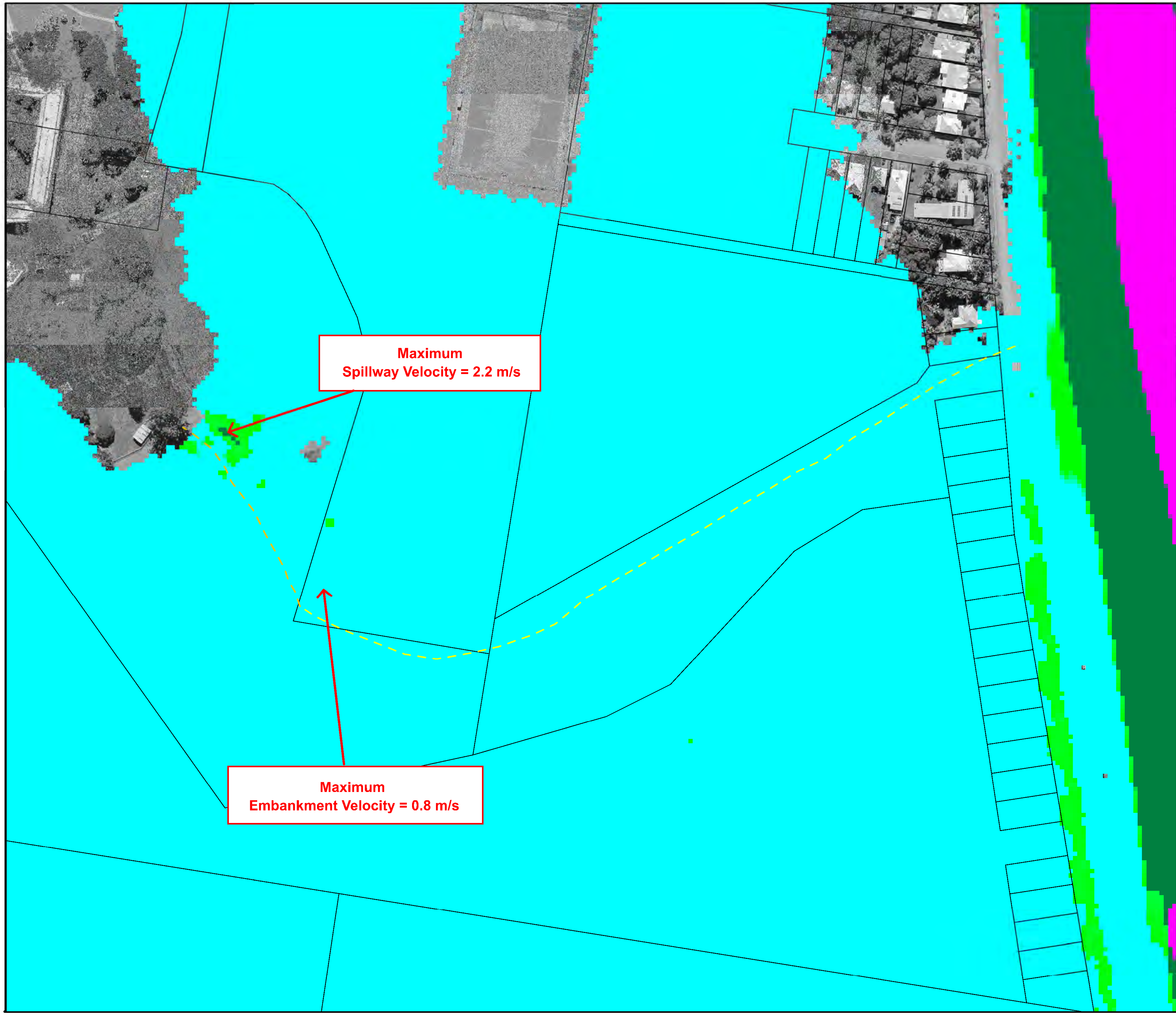
0 0.15 0.30 Km

**Figure 9: Floodwater Depths for the 0.2% AEP Flood for Preferred Levee Raising Scenario**

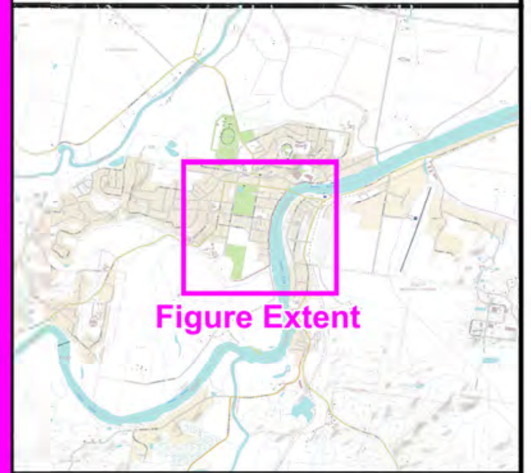
Prepared By:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Fig 9 Depths for the 0.2% AEP Flood for Preferred Scenario.wor




TWEED
SHIRE COUNCIL




## LEGEND

Velocity (m/s)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- Levee Crest
- Spillway Crest

Notes:

Aerial photograph date: 2015

N
W E
S

Scale: 1:5700 (A3)

0 0.10

Km

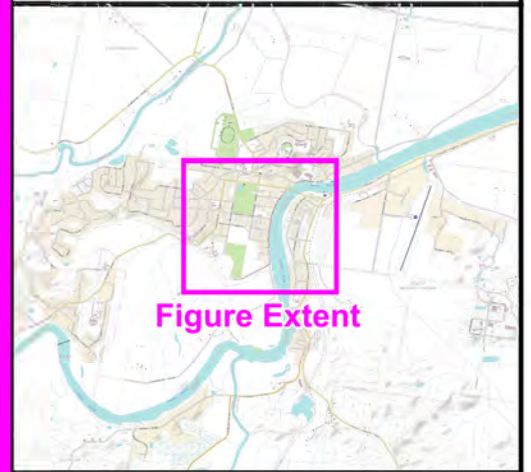
**Figure 10: Floodwater Velocities for the 1% AEP Flood for Preferred Levee Raising Scenario**

Prepared By:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Figure 10: Floodwater Velocities for the 1% AEP Flood for Preferred Levee Raising Scenario.wor


TWEED
SHIRE COUNCIL




**LEGEND**

Velocity (m/s)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- Levee Crest
- Spillway Crest

Notes:

Aerial photograph date: 2015

N
W E
S

Scale: 1:5700 (A3)

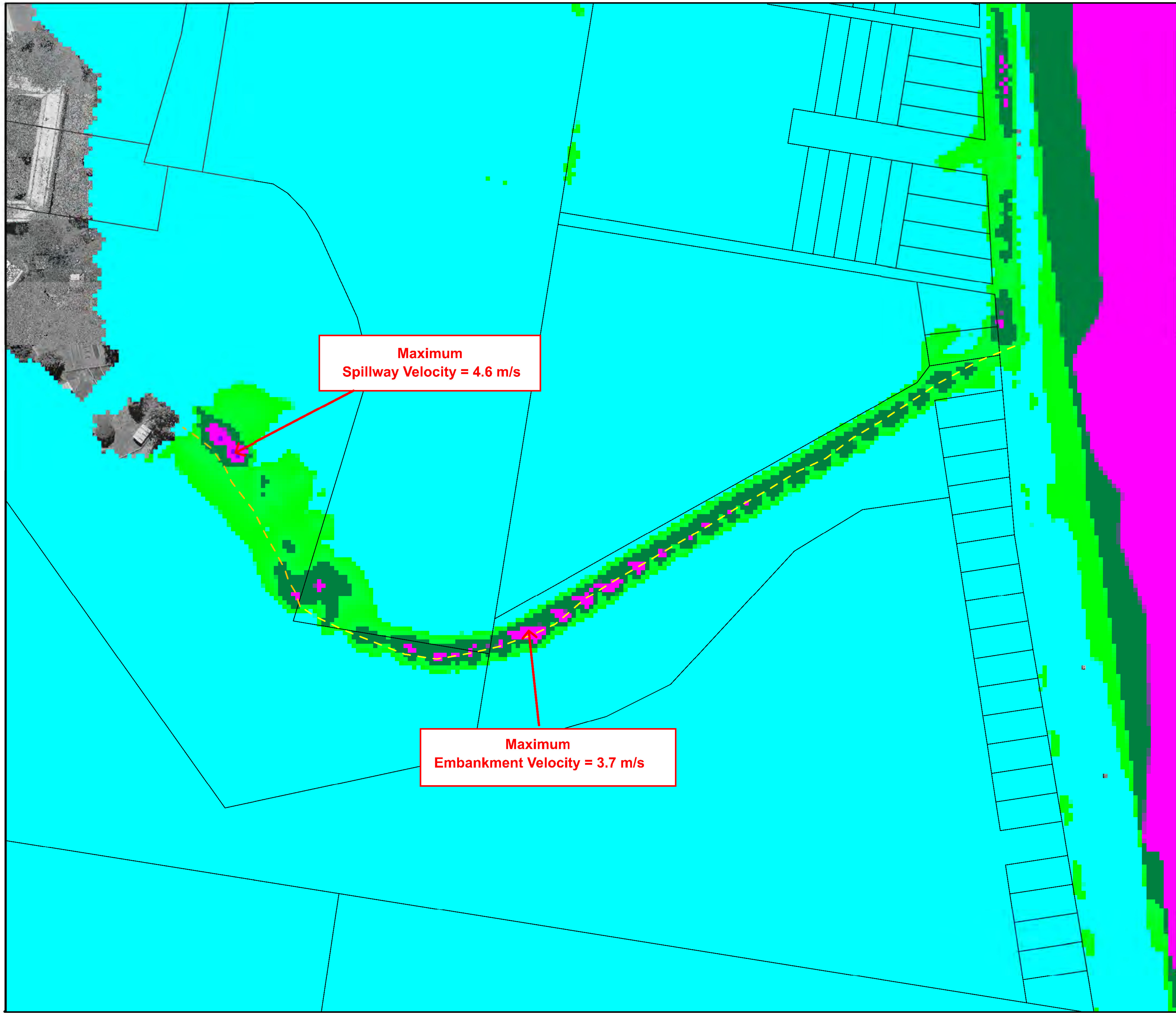
0 0.10
Km

**Figure 11: Floodwater Velocities for the 0.5% AEP Flood for Preferred Levee Raising Scenario**

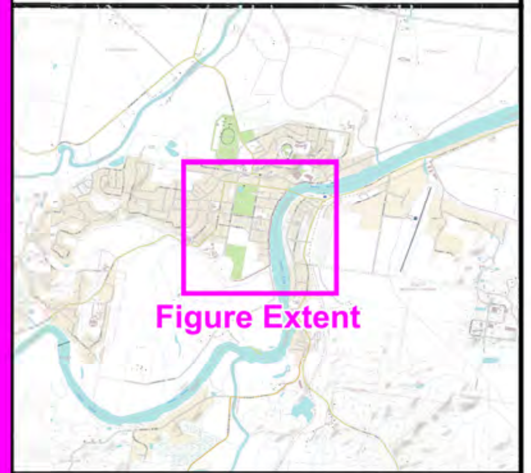
Prepared By:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Figure 11: Floodwater Velocities for the 0.5% AEP Flood for Preferred Levee Raising Scenario.wor




TWEED
SHIRE COUNCIL




**LEGEND**

Velocity (m/s)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- Levee Crest
- Spillway Crest

Notes:

Aerial photograph date: 2015

N
W E
S

Scale: 1:5700 (A3)

0 0.10 Km

**Figure 12: Floodwater Velocities for the 0.2% AEP Flood for Preferred Levee Raising Scenario**

Prepared By:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW 2000

File Name: Figure 12: Floodwater Velocities for the 0.2% AEP Flood for Preferred Levee Raising Scenario.wor

# APPENDIX B

## FLOOD LEVEL DIFFERENCE MAPPING FOR LEVEE RAISING SCENARIO A (+50MM)

## +50mm Levee Raising Scenario

### 1% AEP

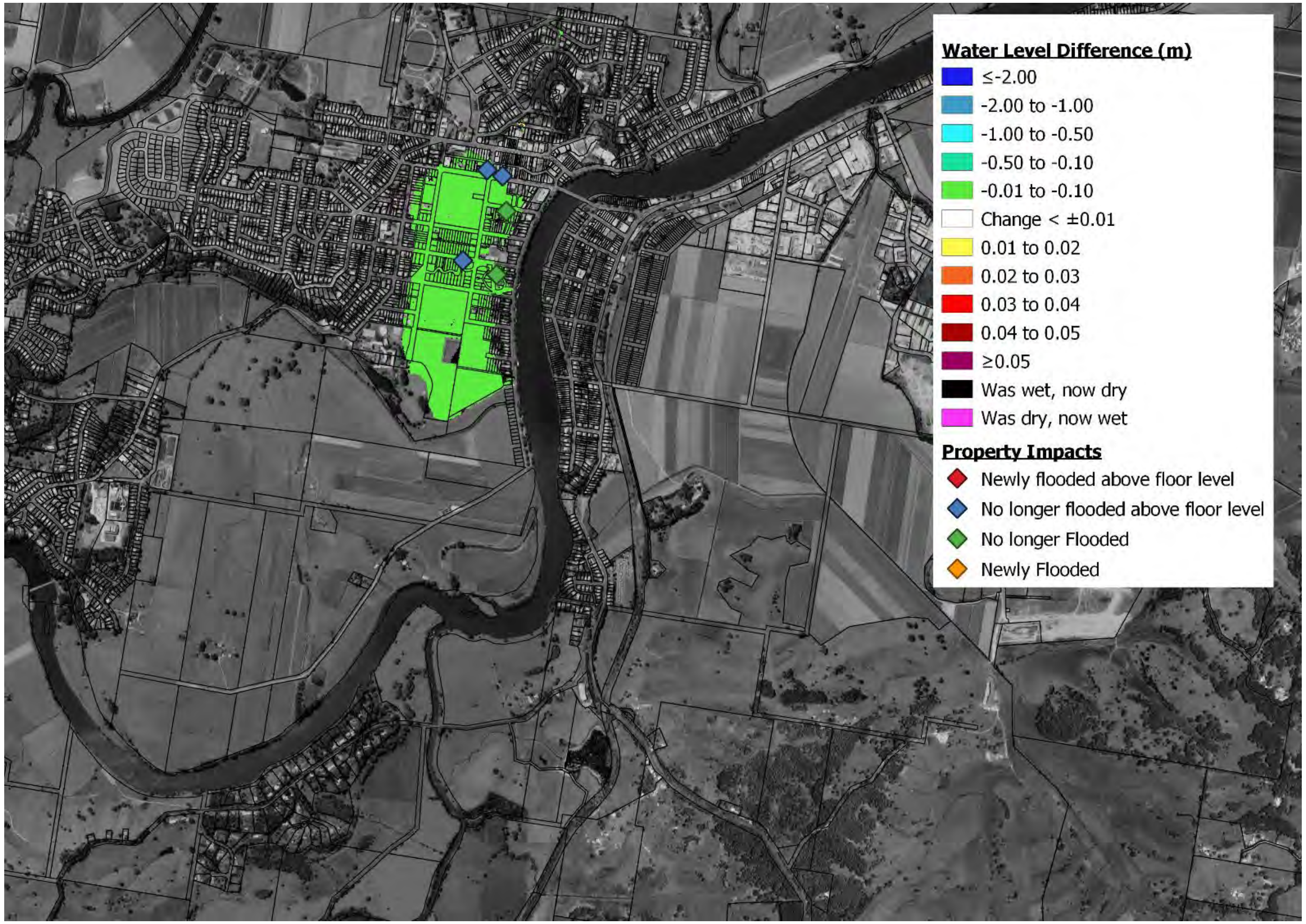



Plate 1 1% AEP flood level difference map for 50mm levee raising scenario

## 0.5% AEP

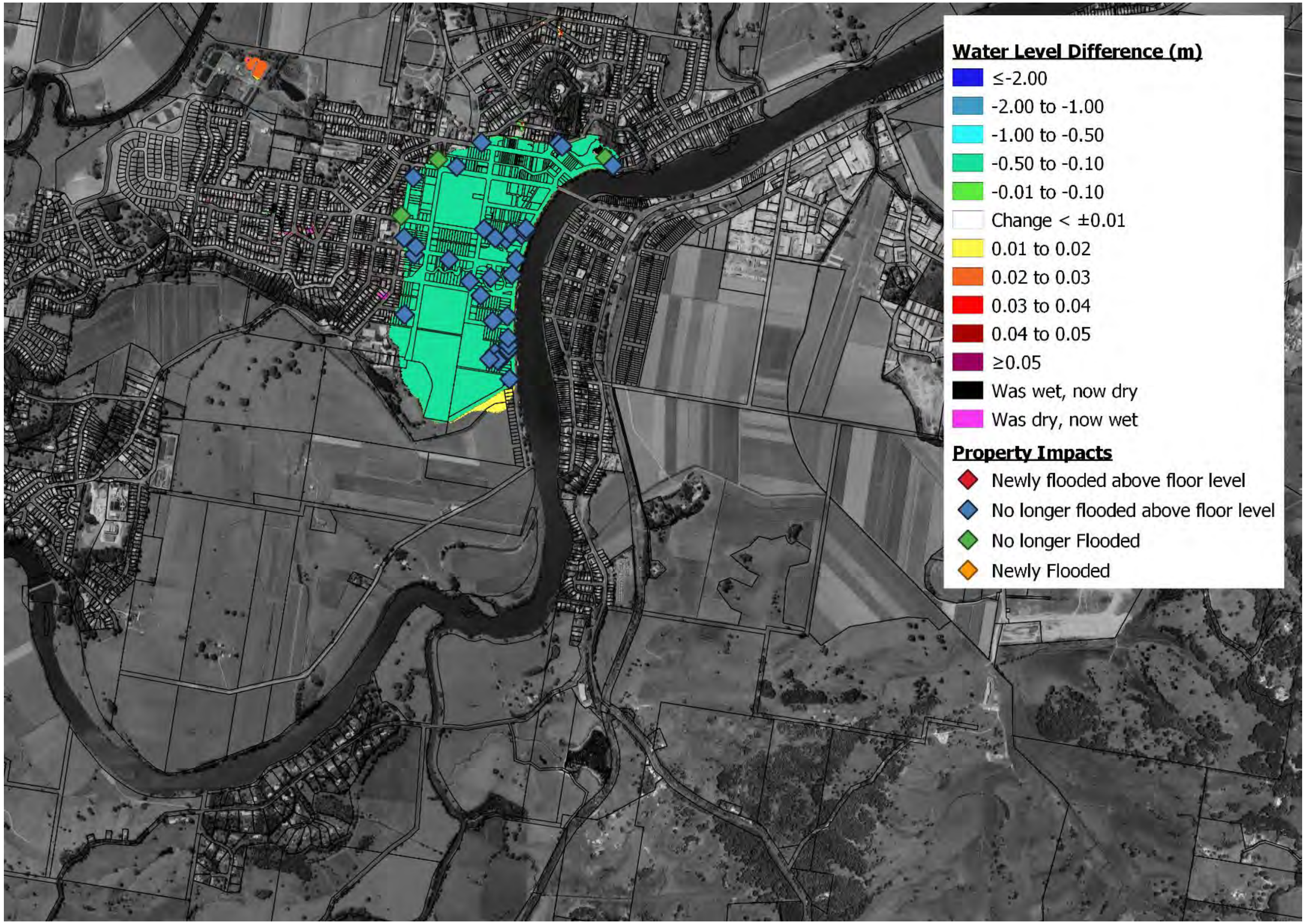



Plate 2 0.5% AEP flood level difference map for 50mm levee raising scenario

## 0.2% AEP

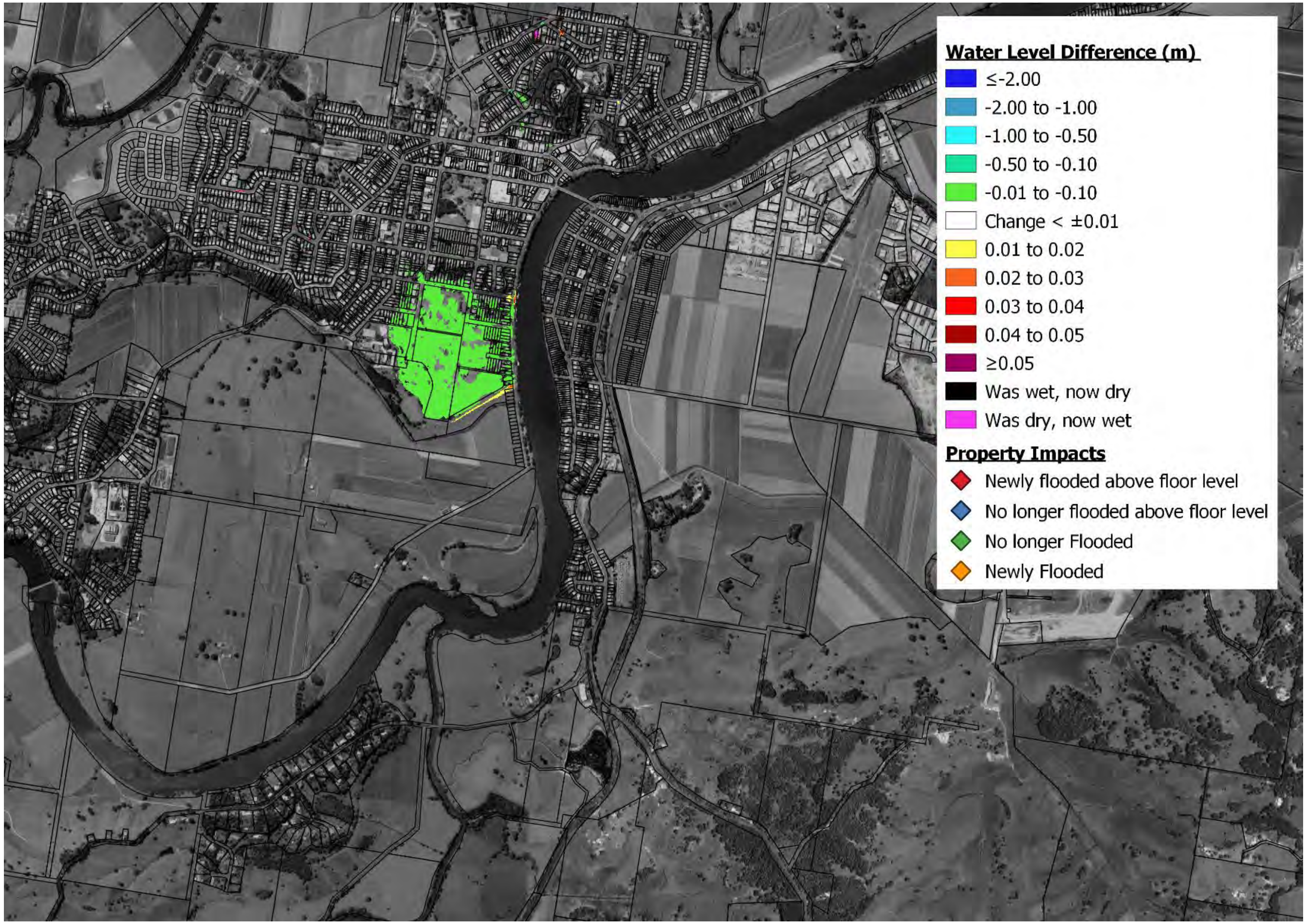



Plate 3 0.2% AEP flood level difference map for 50mm levee raising scenario

# APPENDIX C

## FLOOD LEVEL DIFFERENCE MAPPING FOR LEVEE RAISING SCENARIO B (+100MM)

# +100mm Levee Raising Scenario

## 1% AEP

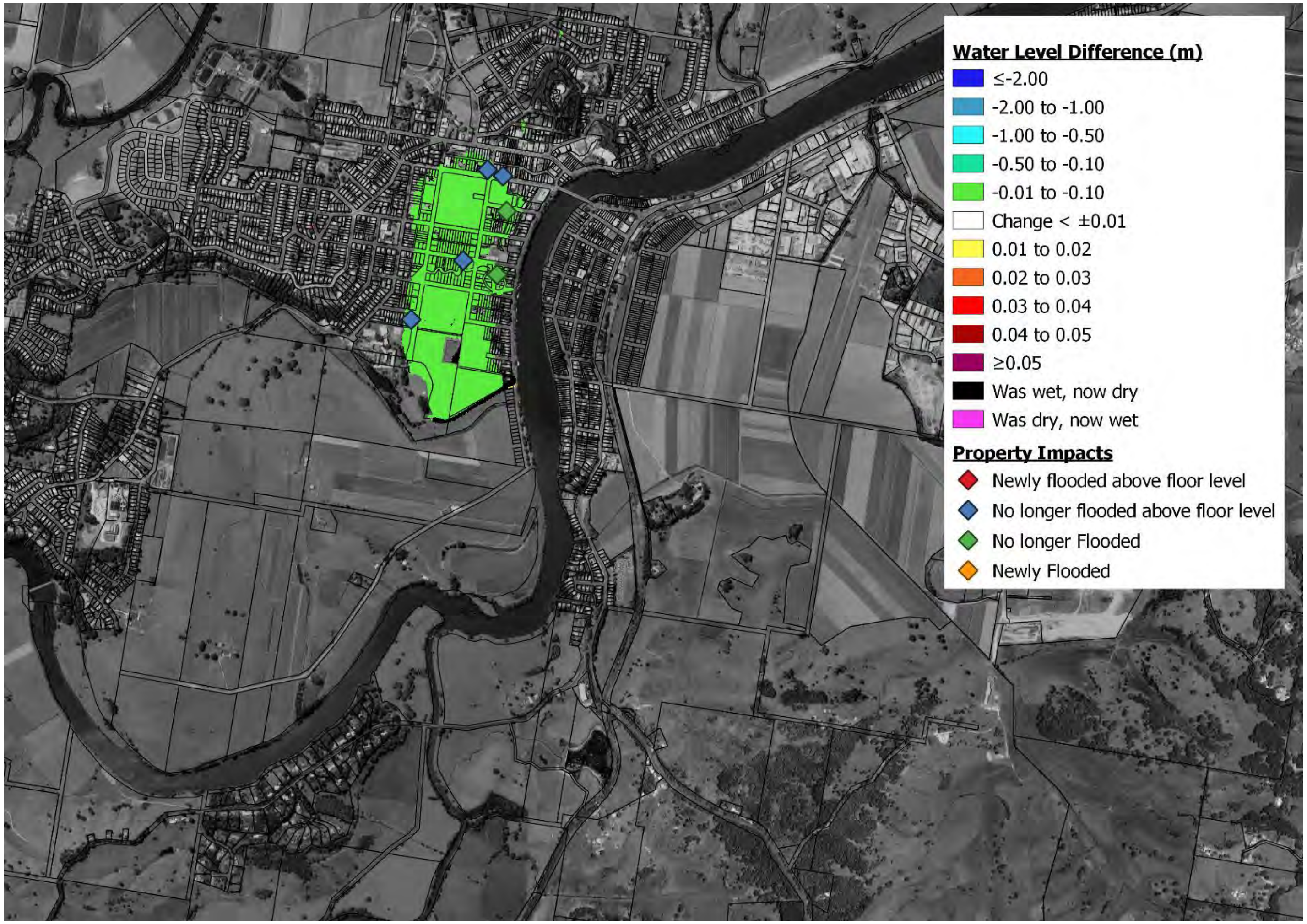



Plate 1 1% AEP flood level difference map for 100mm levee raising scenario

## 0.5% AEP

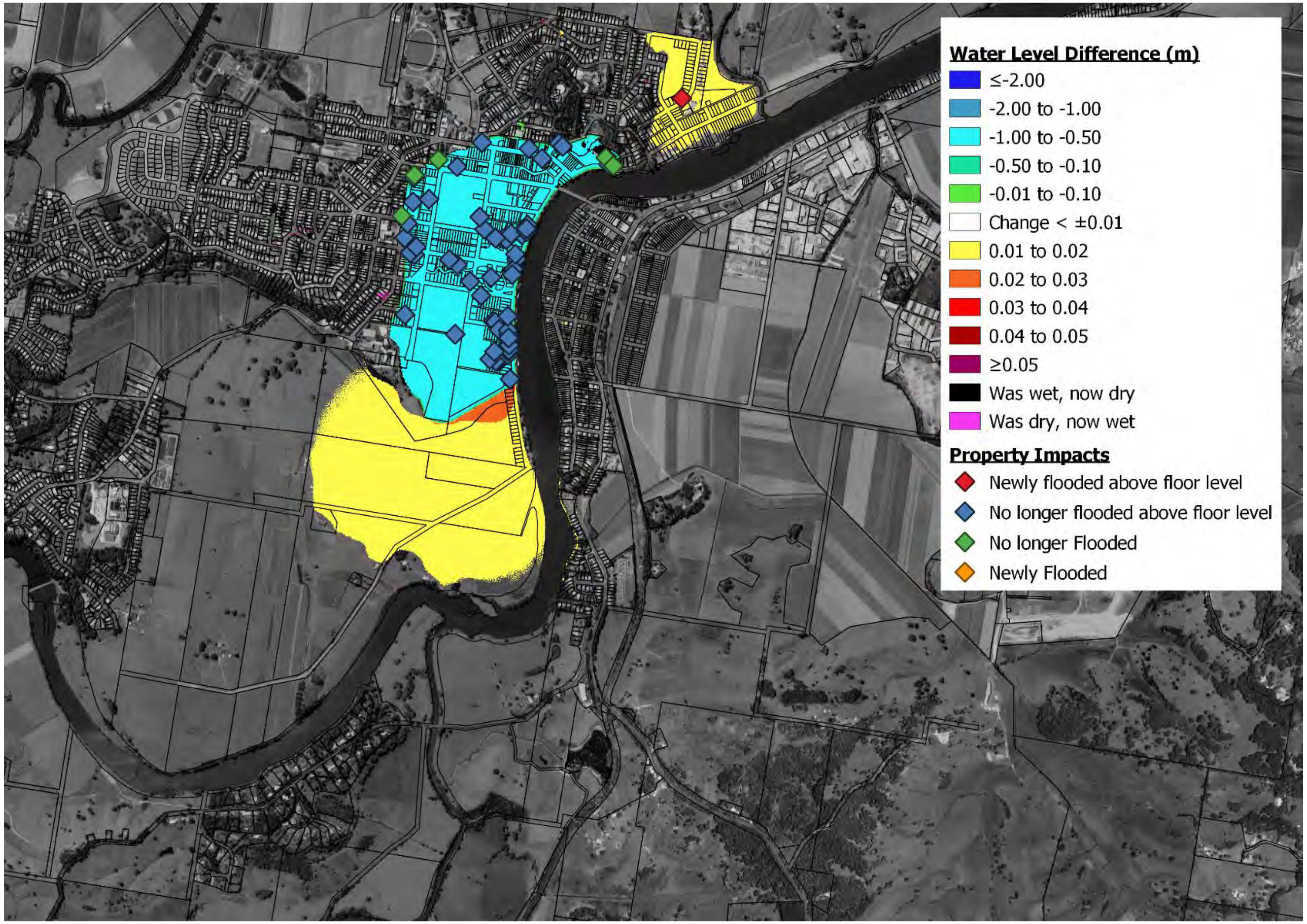



Plate 2 0.5% AEP flood level difference map for 100mm levee raising scenario

## 0.2% AEP

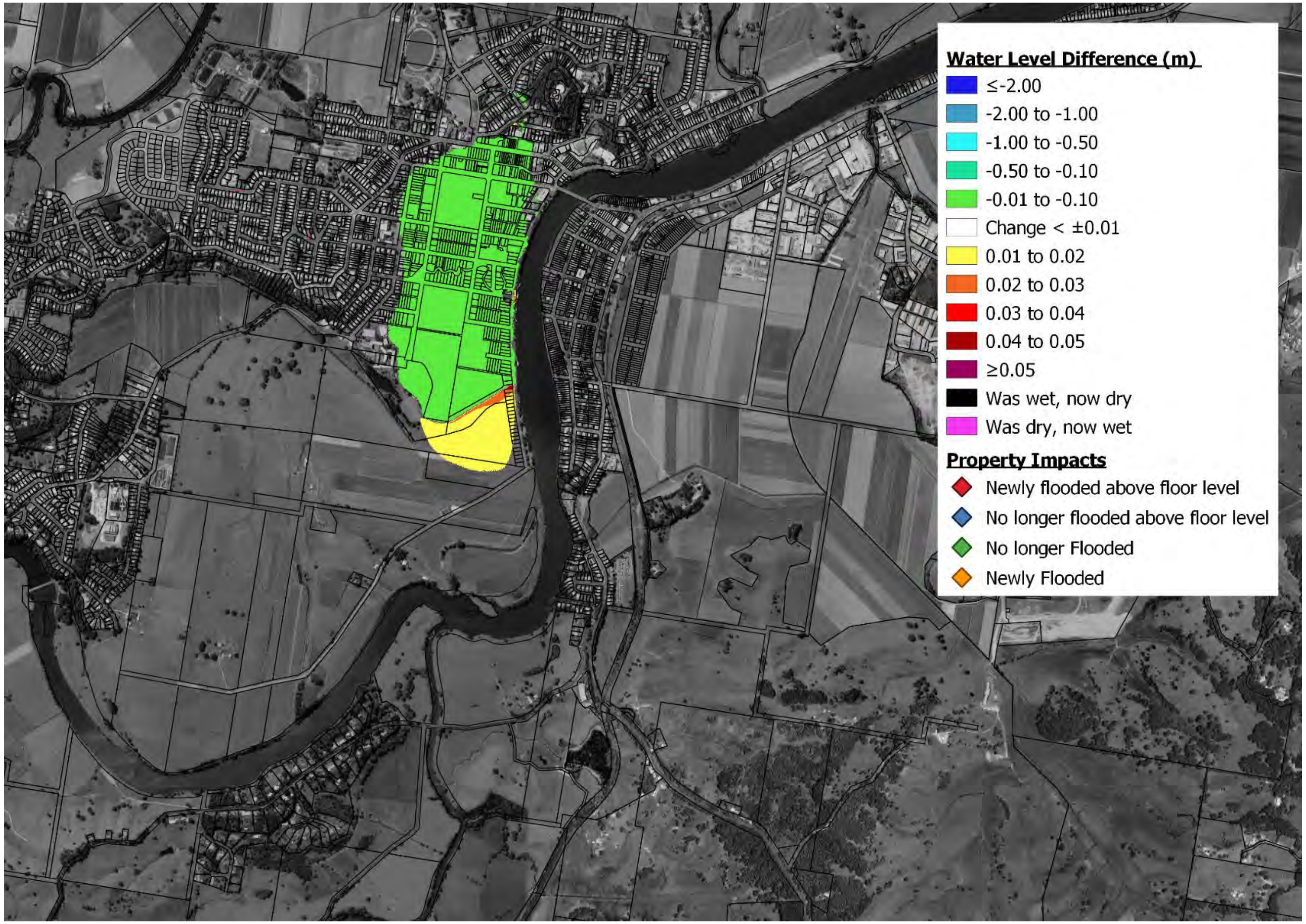



Plate 3 0.2% AEP flood level difference map for 100mm levee raising scenario

# APPENDIX D

## FLOOD LEVEL DIFFERENCE MAPPING FOR LEVEE RAISING SCENARIO C (+200MM)

## +200mm Levee Raising Scenario

### 1% AEP

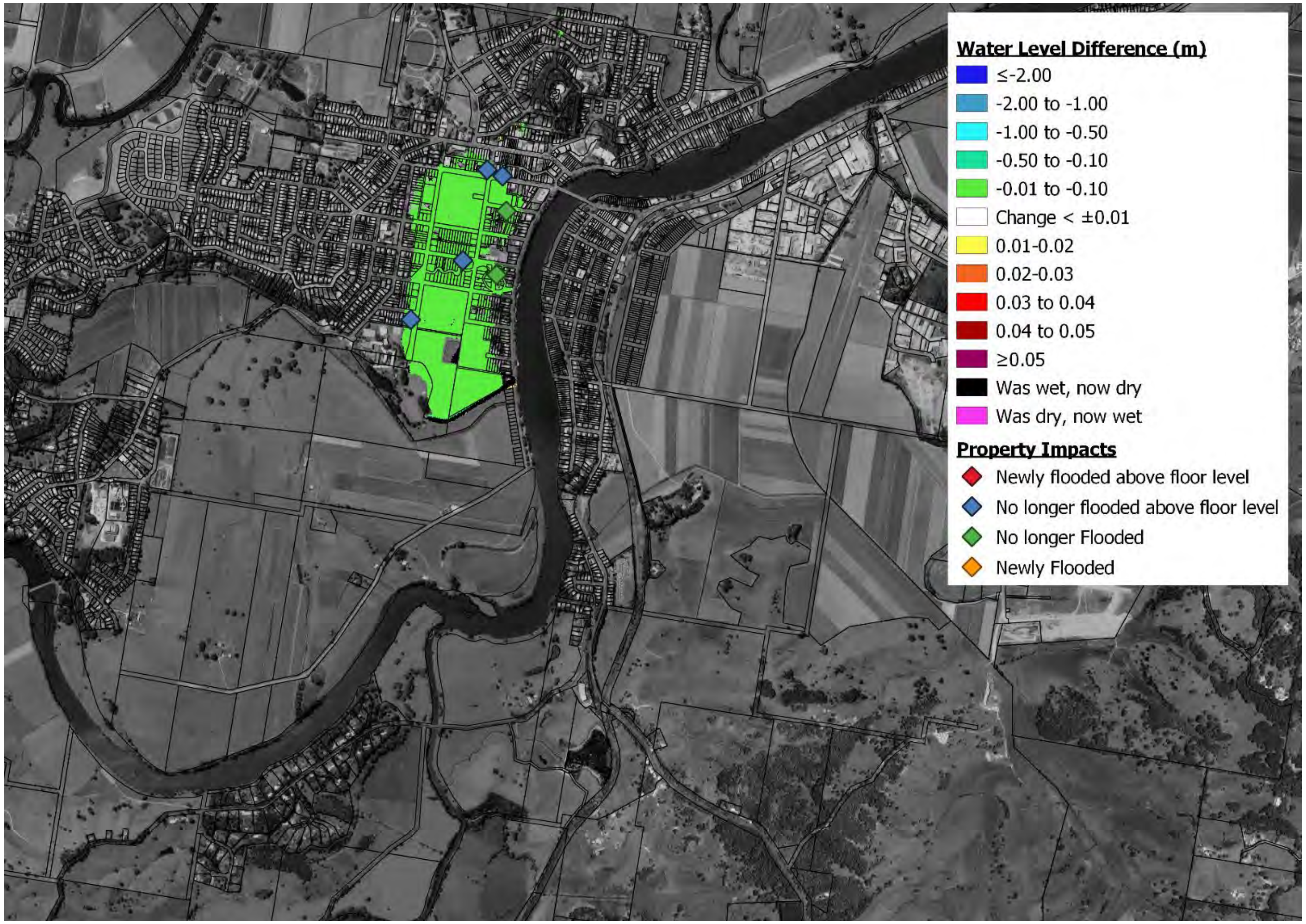



Plate 1 1% AEP flood level difference map for 200mm levee raising scenario

## 0.5% AEP

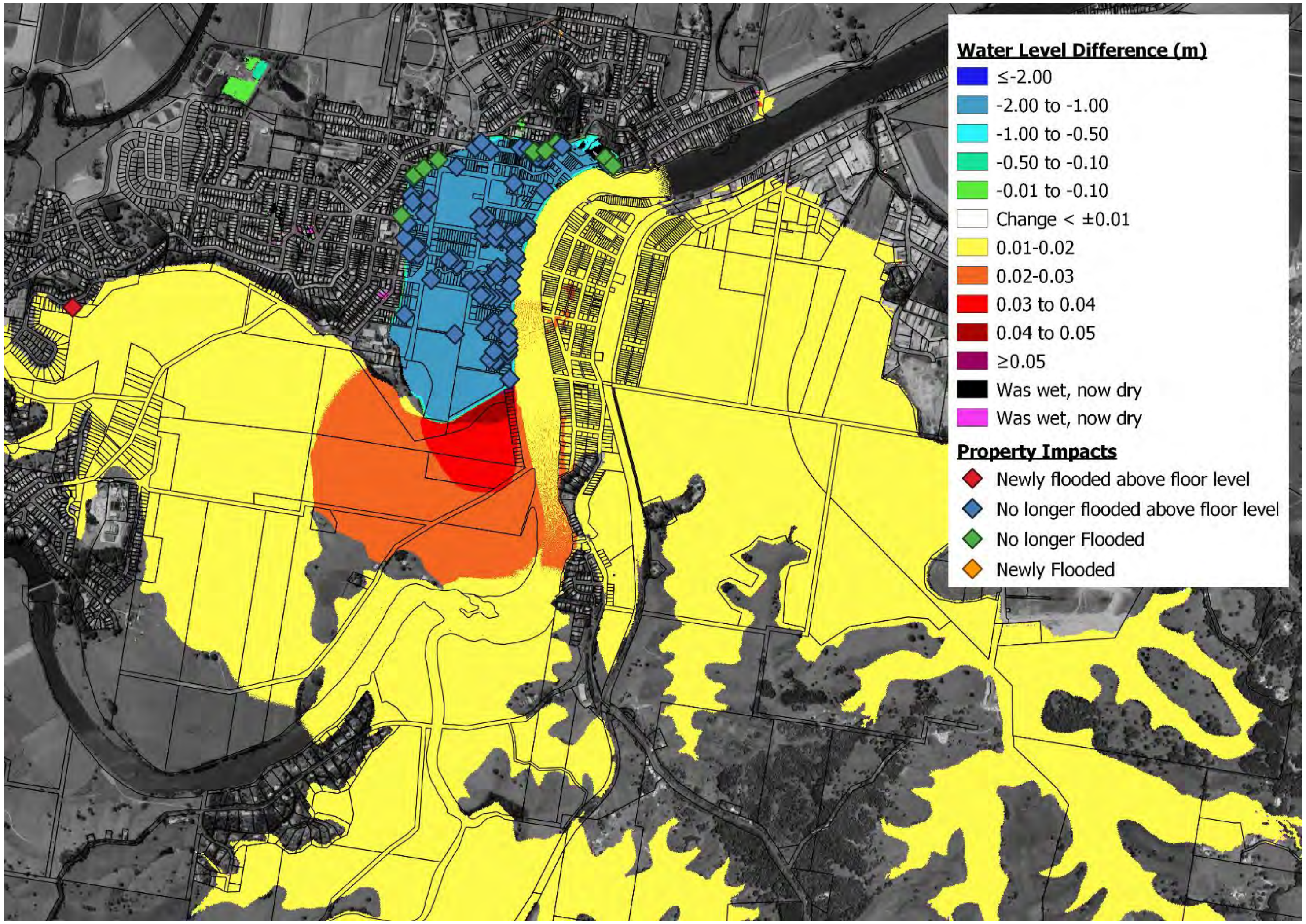



Plate 2 0.5% AEP Flood level difference map for 200mm levee raising scenario

## 0.2% AEP

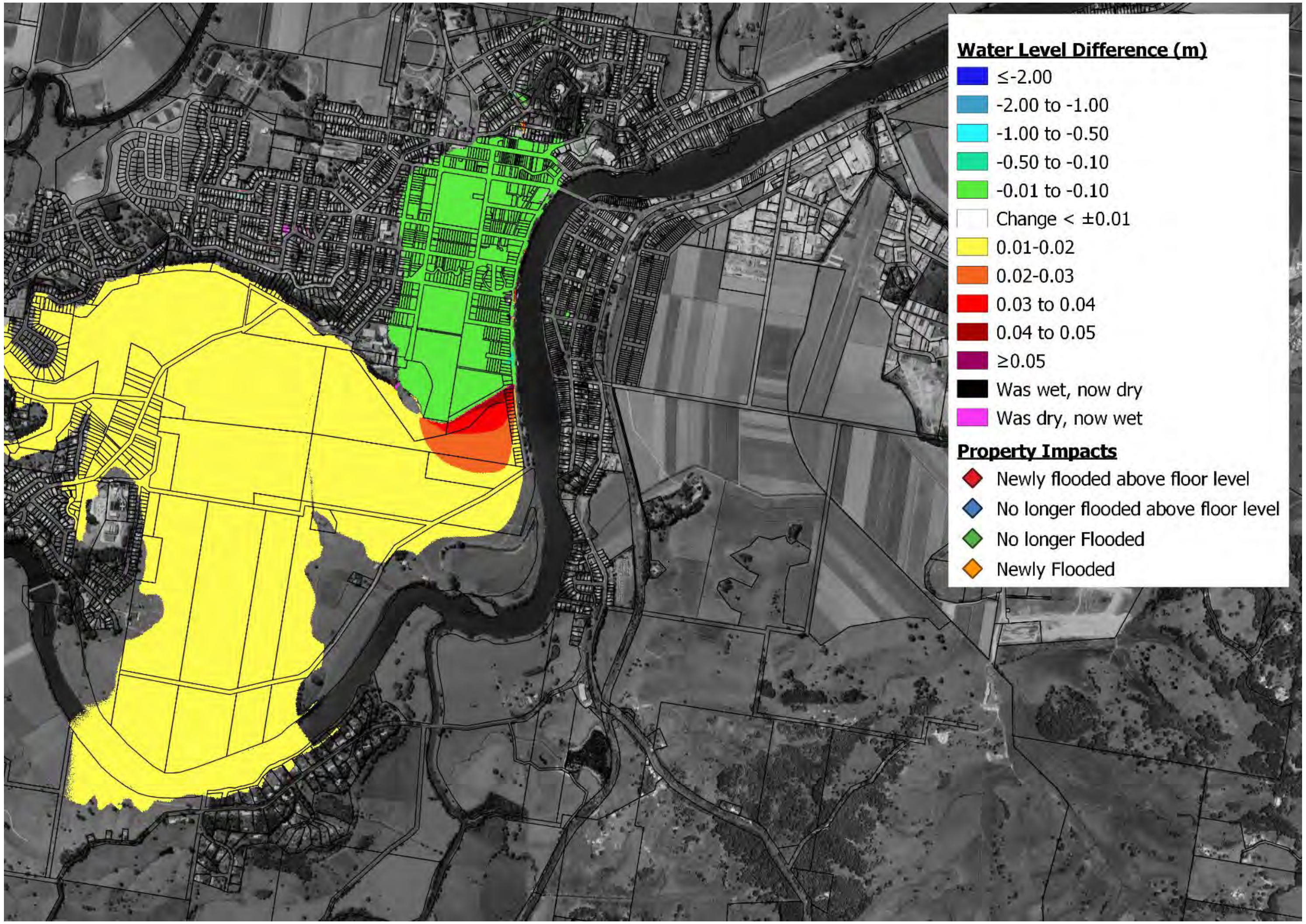



Plate 3 0.2% AEP Flood level difference map for 200mm levee raising scenario